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ABSTRACT

This paper defines, develops, and displays a mathematical modeling formulation for exploring decisions available to the higher educational administrator in evaluating discrete educational program budgets (instructional, service, and administrative) for possible future funding alternatives. Complex budget reduction strategies can be computer-modeled through the use of simple integer programming (mathematical modeling) techniques over graduated budgeting scenarios. With each such graduated reduction alternative identified as, for example, a 5 percent decrease or 3 percent increase, all possible graduated budgeting changes are evaluated internally to this particular budget and externally as compared to other similar programs under evaluation. Using multivariate criterion references as numerical indexes against which to compare the multiple budgeting alternatives, a finite group of feasible solutions is computed, and a single final (optimal) solution identified. This entire computer-modeled process has been validated in such contexts as the closing of elementary schools in a metropolitan area and the budget reductions for a suburban rural school district. A 16-item list of readings and references is included. (Author/TE)

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REDUCING HIGHER EDUCATION BUDGETS THROUGH MULTIPLE ALTERNATIVES MODELING™

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ABSTRACT

Complex budgeting reduction strategies for colleges and universities can be computer-modeled through the use of simple integer programming (mathematical modeling) techniques over graduated budgeting scenarios.

SUMMARY

An approach for determining fiscal reduction decisions at the college and university levels is achieved by viewing the reduction of a program budget as a graduated increase/decrease strategy. With each such graduated reduction alternative identified as, for example, a 5-percent decrease or 3-percent increase, all possible graduated budgeting changes are evaluated internally to that particular budget and externally as compared to other similar programs under evaluation. Using multivariate criterion references as numerical indices against which to compare the multiple budgeting alternatives, a finite group of feasible solutions is computed, and a single final (optimal) solution identified. This entire process is computer-modeled, and has been validated in such contexts as the closing of elementary schools in a metropolitan city of 200,000 populace and the budget reductions for a suburban rural school district.

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D E D I C A T I O N

This project is dedicated to all institutions of higher education, whether dead or dying, who unfalteringly and unfailingly clung to the end to the basic principles of allocating resources during periods of fiscal crisis:

> Thou shalt not renew the continuing contracts of non-tenured, tenure-track faculty before studying the effectiveness and viability of tenured faculty;
>
> Thou shalt not assess the past nor current efficacy of instructional and service programs, nor their predictable decline towards obsolescence, before refusing to support new and dynamic efforts at developing timely responses to current demands of the environment and society;
>
> Thou shalt not allow trivial standards pertinent to effectiveness, efficiency, satisfaction or economy to guide the decisionmaking process during fiscal exigency; and,
>
> Thou shalt not subscribe to the philosophies of strategic planning, program review and evaluation, and the simulation modeling of alternative decisions based upon data.

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MISSION

The purpose of this paper is to define, develop and display a mathematical modeling formulation which has significant potential for exploring the myriad of decisions available to the higher educational administrator when faced with the need to evaluate discrete educational program budgets (instructional, service and administrative) for possible future funding variances.

An appropriate mission statement of such a model for educational fiscal crisis budgeting would be formulated as:

> **To design a system of alternative budgeting alternatives, based upon likely scenarios for the future needs and demands of the university, and its individual colleges and/or schools which could be compared and evaluated against established policy standards, and instructional and administrative requirements, and which would result in the selection of which program budgets will be reduced, and by how much.**

A system of seven (7) goals can also be stated which would support the adequate and appropriate accomplishment of this mission in crisis budgeting evaluations and assignments:

> Goal 1. Prepare, for each program budget, the types and amounts of budgeting reductions which could be reasonably applied to the program budget, and in addition, prepare a narrative which would best describe the program after each type/amount of reduction;
>
> Goal 2. Define, across all program budgets, those measures of criterion reference which would best describe the resource needs, program contributions to university and individual college and/or school goals, and internal/external perceptions of the programs whose budgets are being evaluated;
>
> Goal 3. Select, for each criterion reference defined in Goal 2, the maximum (in the case of negative impact) and minimum (in the case of positive impact) effects to the university and individual colleges and/or schools which are sought based upon the types of programs reduced, and the amounts of each of their reductions;
>
> Goal 4. Assure, for each program being evaluated, that one and only one level (or type) of reduction (if any) is selected;

Goal 5. Determine which of the criterion comparison references, defined in Goal 2, will be utilized to guide the final selection of which budgets will be selected for reduction, and the amount of that reduction, in the event that multiple university program reduction strategies become available to the university president, college deans, and school directors and/or chairpersons;

Goal 6. Validate, for each of the criterion references utilized for determining the final types and amounts of program reductions, the extent to which each of these criterion references significantly determined the final selection of those programs for reduction, and the amount(s) of those reductions; and,

Goal 7. Correlate, in terms of the programs chosen for reduction and the weights associated with each of these reductions, the final overall reduction strategy of the university and the accuracy with which the university and individual colleges and/or schools can honestly trust the results of strategy.

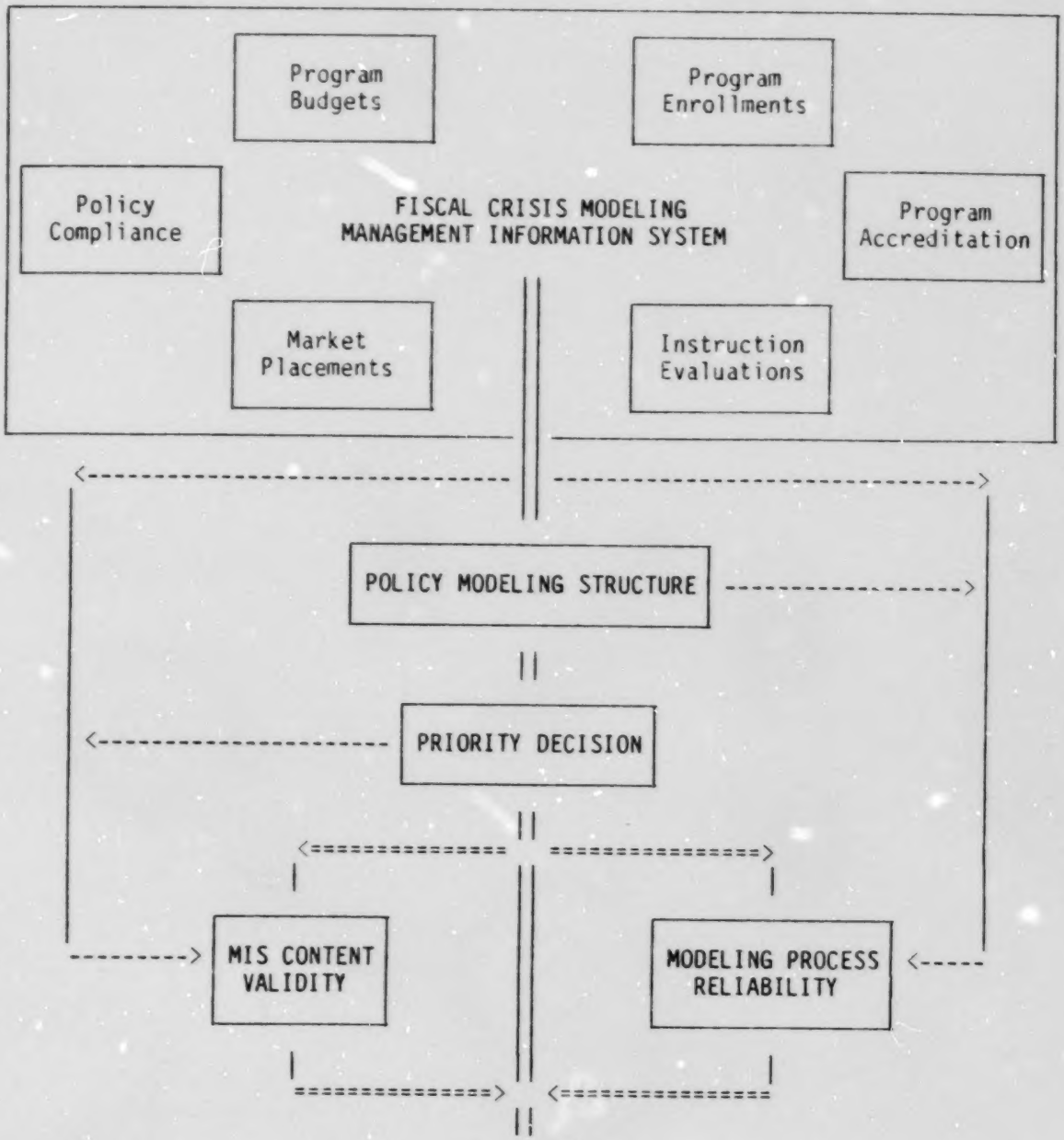
This modeling technique allows the decisionmaker to utilize all available data and information for simulating the impact to the university which alternative funding levels per each individual program might provide. This forecasting strategy includes the ability to control for interrelationships between discrete pairs of programs, as well as among the collective impact of groups of programs with their individual levels of recommended funding. Finally, this modeling strategy allows the decisionmaker to vary the initial controls placed upon the model's mathematical structure, thereby simulating alternative decisional solutions based upon an ever fluid and transactional environment.

BACKGROUND

Problems related to program budgetary requirements in higher education (identification, assignment and resulting influence) have become a major part of the higher educational administrator's scope of decisioning during the past five years. Difficulties similar to those experienced at Fisk University (for more information, see Chronicle of Higher Education, Vol. XXVIII, No. 24 (August 8, 1984), pp. 1,13) present signficant problems for most institutions of higher education, not only in the United States but also Canada (British Columbia), the Middle East (Israel), South America (Brazil) and Africa (Nigeria).

What has been needed, but until recently generally ignored, is a method for simulating the university's budgeting environment (viz. expected impact of levels of funding in terms of corresponding levels of resulting program effectiveness) beyond those provided by the more generally understood techniques of cost-benefit and cost-effectiveness analyses. Specifically, a model which could identify several alternative funding assignments for each program, and summarily choose which funding level for which individual program across all collective programs best fits the desires, needs and constraints of the university's environment, would significantly enhance the university's budgetary decisional requirements.

The model presented in this paper views the crisis budgeting decisional environment as one of a dynamic nature, where information entering the model is highly variable and must be updated regularly. In addition, any such dynamic modeling of a highly variable environment must be able to evaluate the changing feasibility of potential alternative decisions as the parameters for selecting these decisions (themselves) change. Such an environment for dynamic modeling might be generally construed as follows.



VALIDATION OF POLICY MODELING TECHNIQUE, and
SUPPORTING MANAGEMENT INFORMATION SYSTEMS

In 1978, a rather simple though comprehensive modeling approach was attempted in the initial targeting of specific elementary schools for future

closure in a school district serving a population center of approximately 180,000 people in the State of Wisconsin. The model's results identified the number of schools which were to be recommended for closure, by name, and with supporting rationale for each school's selection. In 1981, a reformulized model was applied to the needs of a small school district in the State of Washington where the superintendent had to cut not less than 213 thousand dollars from an existing district budget of 893.5 thousand dollars (24 percent reduction) with an accompanying specific rationale for each of the individual program reductions which collectively formed the recommended fiscal roll-backs.

These models, and others developed by the author, represent reformulizations of operations research techniques which typically determine product distribution routes for transportation and personnel assignment strategies for product service delivery. The technical models themselves, commonly refered to as binary (1,0) integer programming formulations, are little more than systems of simultaneous linear inequalities and equations, whose dependent variables (i.e. the alternatives being evaluated and compared) take on the value of '1' for each alternative which is a member of the "solution set of alternatives", and the value of '0' otherwise. Constraints to this decisional process are represented in the form of linear inequalities and equations, and the single, best solution then chosen from the range of feasible, alternative solutions through the deployment of a single vector sum known as the objective function value.

TYPE OF MODEL

The technical description of the modeling formulation for determining which program budgets will be targeted for a funding variance, and the extent of that variance (i.e. increase or decrease in funding), must include components of simulation modeling related to the model's ability to be hierarchical, variable level, exclusive, exhaustive and simultaneous.

Hierarchical Decision Modeling. A hierarchical decision model is one where the alternatives (range of potential decisions) represent levels of a decision, such as might be reflected in the questions:

"Which programs should be assigned a funding variance?"

"Should that variance be an increase or decrease?"

"To what degree should that increase or decrease be assessed?"

Thus, and as will be discussed in the next section, the alternatives available to the model for determining budgetary variances for programs in higher education represent a comprehensive approach to a very complex problem. In the budget reduction model presented in this paper, each of these three levels of decisioning are adequately simulated and evaluated.

Variable Level Options. Hierarchical modeling structures may be either fixed or variable level. Fixed level means that the lowest level in the alternative decisional hierarchy available for evaluation and comparison is the same in number and type for each of the alternatives identified in the highest level of the hierarchy. The model which identifies schools for future closure is a fixed level model, in that the same five (5) lower-level hierarchical alternatives (closure with sale, closure with lease, closure with mothballing, partitioning with lease, and continued full operation) are available for each of the school sites being modeled.

The budget reduction model is variable-level hierarchical, and as such allows different numbers and/or types of lower-level hierarchical alternatives across each of the higher-order alternatives. This represents the use of a graduated reduction scheme, in that some budgets may have several levels of percentage reductions being considered, while other have only a few. Some programs may be evaluated for potential increase in funding, while others have the simple alternative of remaining solvent at current funding levels (called zero-budgeting or stasis) or terminating their operations (100 percent funding reduction) in the future.

Discrete Options as Mutually Exclusive. In the graduated budget reduction scheme for higher education, two internal controls must be effectively implemented through model design.

First, each alternative option must be designed so as to represent a mutually exclusive relationship with each of the other options. Thus, if option 'a' includes some or all of the ingredients of another option, say 'b', then 'a' must be formulated with these ingredients internal to its own structure without the necessity of choosing 'b' in consort with 'a' if a combination of such ingredients are desired in the final solution. Furthermore, the characteristics of 'a' must not be equivalent to 'b', although 'a' may contain all of 'b' in addition to other ingredients not found in 'b'.

Second, the choice of a particular lower-order hierarchical option for each higher-order alternative must be singular, or discrete. Thus, choosing alternative 'a' must necessarily preclude any subsequent selection of 'b', 'c', ... for that particular higher-order alternative. Therefore, if program 'A' has three lower-order alternatives for funding reductions, say '3%', '5%' and '8%' options, then the model's determination of an 8 percent reduction must be identified as the selection of the '8%' option, and not the multiple selections of both the '3%' and '5%' options.

Grouped Options as Collectively Exhaustive. The graduated budget reduction model not only controls adequately for both of these "discrete" and "exclusive" factors, but in addition guarantees that all options are equivalently evaluated and each program assigned a resulting funding variance dependent upon the data available for such comparisons. Not only does each program have a potentially variant number of options available for evaluation, but the set of variable level options assigned to each program is exhaustive of all potentially reasonable (and unreasonable) alternative funding variances which must be considered.

Identified Solutions as Feasible, Alternative and Simultaneous. The graduated budget reduction model for programs in higher education identifies (if in actuality solutions exist) all possible subsets of alternative solutions which are feasible according to the constraints placed upon the model itself. These alternative subsets of available solutions that fit the decisionmaker's modeled constraints, i.e. are feasible, are guaranteed to not violate any of the constraints intially placed upon the model's formulation. Thus, all feasible,

alternative solutions are said to be simultaneous -- simulataneously in compliance with all established modeling constraints.

COMPONENTS OF THE GENERIC MODEL

The mathematical formulation utilized for the graduated fiscal budgeting model is that of the Multiple Alternatives Model™ (Wholeben, 1980). MAM™ is a educationally oriented revision of binary (1,0) integer programming, and represents a mathematical system of linear inequalities and equations composed of:

[1] two (1) label definition vectors (the alternatives and criteria labels vectors);

[2] one (1) rectangular matrix (the coefficient matrix);

[3] two (2) column data declaration vectors (the condition vector and bounded limits vectors), collectively known as the right-hand-side or RHS;, and

[4] one (1) row data declaration vector (the objective function).

Development of the multiple alternatives modeling system is performed in a strict sequence of activities, defined by the product which results from each particular activity. This developmental sequence is described below, including a brief statement of the function of that particular product for later system definition and modeling control.

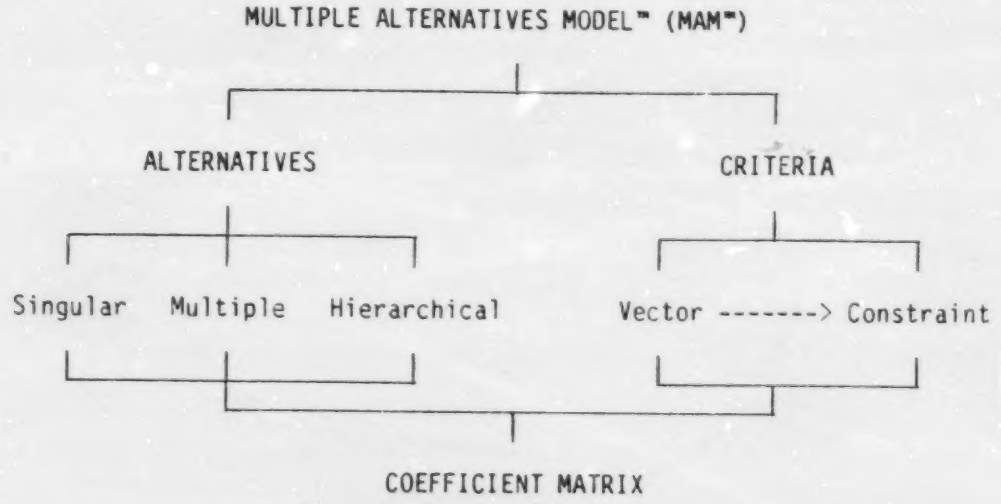
MULTIPLE ALTERNATIVES MODEL™

(Components)	(Functions)
ALTERNATIVES (LABELS) VECTOR	defines the discrete decision alternatives which will be compared and evaluated during the execution of the MAM™ model
CRITERIA (LABELS) VECTOR	defines the particular criteria which will direct the execution of the model in selecting those subsets of alternatives which are feasible as solutions under the criterion standards imposed
COEFFICIENT MATRIX	contains those values for each alternative (column) measured against each criterion standard (row) evaluating each alternative's comparative worth
RIGHT-HAND-SIDE (RHS)	composed of an algebraic condition ($\leq, =, \geq$) and a bounded limit, this component transforms the coefficient matrix into a system of linear inequalities and equations, known as the constraint matrix
OBJECTIVE FUNCTION	contains values of an unbounded vector which will be used to select which single subset of feasible alternatives provides the best (optimal) solution under the conditions imposed by the constraint matrix

The development of the graduated crisis budgeting model from the more generic MAM™ framework is sequencial, and involves a number of design decisions according to the mandates of the particular decisional environment being modeled. To illustrate this, each section (or phase) of MAM™ development will

be displayed in greater detail, and a number of comments related to crisis budget modeling offered to the reader.

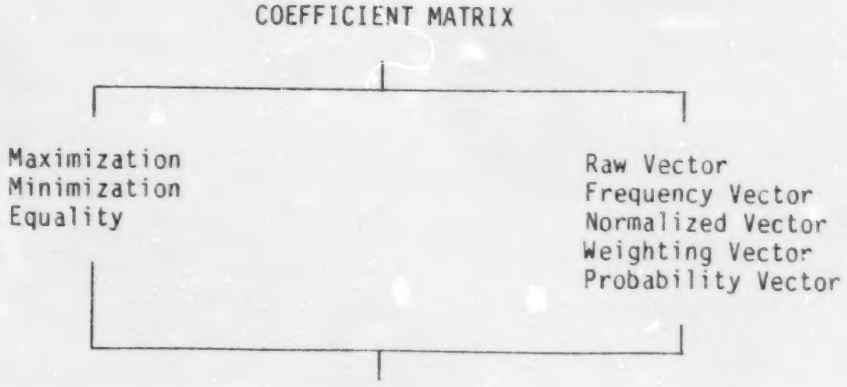
The first stage of modeling development involves the design of the alternatives and criteria (labels) vectors in advance of gathering the necessary measures for incorporation into the coefficient matrix.



The graduated approach to crisis budgeting requires that a hierarchical approach be taken during alternatives vector design. As is true for all MAM™ designs, the development of each criterion vector must take into account its later use as a constraint (algebraic inequality or equality) for the evaluation, comparison and selection process.

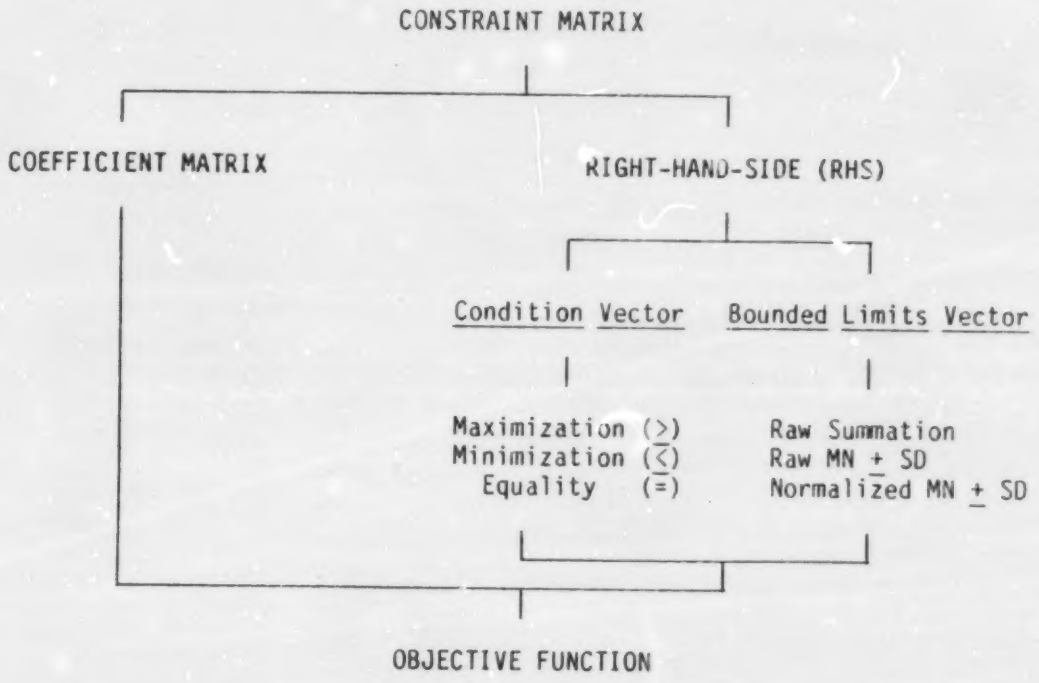
Design and construction of the coefficient matrix requires the developer to first choose what type of vector/constraint is to be modeled; for example, a maximizing vector which will be utilized as a maximizer constraint, attempting to secure that mix of alternatives which maximizes some perceived good or benefit, as opposed to a minimizing vector which will be utilized as a minimizer constraint, attempting to secure that mix of alternatives which minimizes some perceived negative effect or injurious worth. Secondly, the developer must select what type, format and scaling of values for each vector will be utilized

to display the positive or negative impact associated with each alternative's worth.



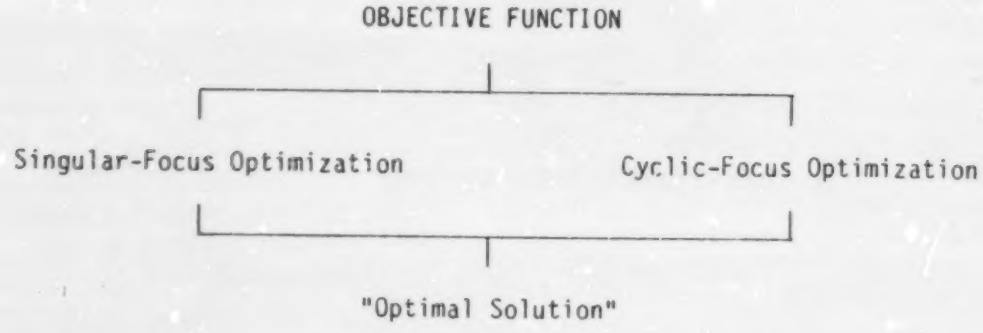
The graduated crisis budgeting model utilizes all three types of constraint conditions ($\leq,=,\geq$) and may employ each of the five measurement formats (raw, normal, etc.) available to the model based upon designer needs. Normalized and frequency (counting) vectors are the predominant choice for most budgeting situations. All four of the standard measurement scales (nominal, ordinal, interval and ratio) can be reliably introduced into the model.

The constraint matrix is simply a merger of the coefficient matrix and the right-hand-side (RHS) composite (condition vector and bounds vector), forming the system of linear inequalities and equalities which will constrain the final selection of the alternatives for membership within the solution set. Most problems associated with the proper use of the constraint matrix arise from an inappropriate development of the bounded values vector within the right-hand-side.



For the graduated budgeting model, the use of normalized values for the coefficient matrix and the RHS is strongly recommended. Some criterion foci will have both raw and normalized vectors reflecting their influence upon the model, since raw values will control for specific criterion impact while the normalized transformations of these raw values will control for relative impact compared against the distributional qualities collectively of that particular criterion's measures.

The final component of the Multiple Alternatives Modeling™ framework for constrained decision selection is the objective function, or optimality vector. The objective function is either a raw or normalized values vector which is used to select the best (viz. optimal) subset of alternative solutions, from the larger subset of all feasible subsets of alternative solutions generated by the model. The use of a single objective function is known as singular-focused optimization, and is the conventional approach. Using several objective functions, and studying the impact upon the system by way of the different solutions selected by the model for each objective function used, is known as cyclic-focused optimization, and is the preferred approach.

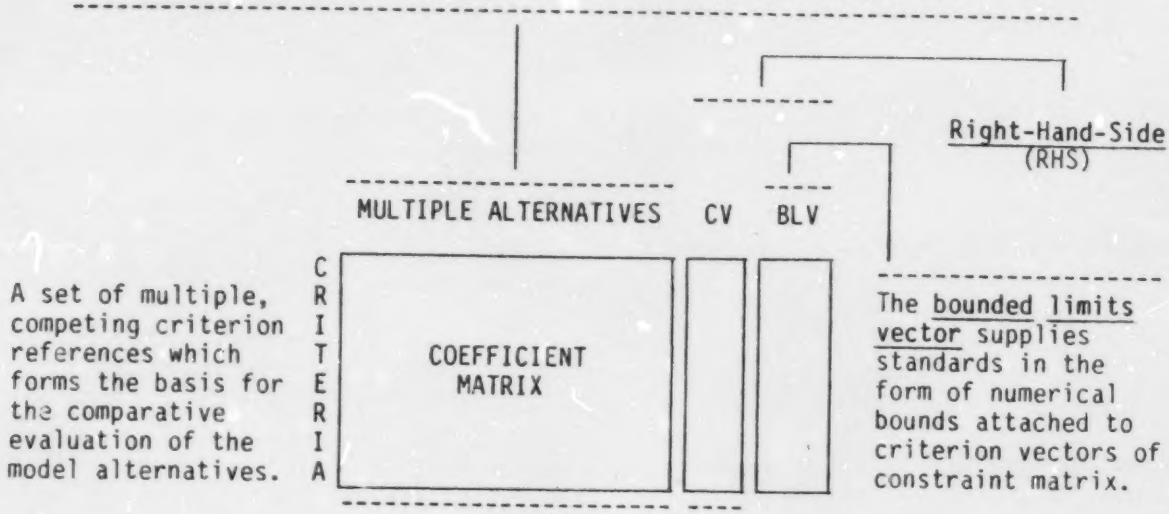


The graduated budgeting model employs the cyclic approach, and employs a wide range of both parametric and nonparametric statistics to perform post-hoc analyses on the variance in alternative solutions observed.

In summary, the general Multiple Alternatives Modeling™ framework employs a number of discrete vectors and a single rectangular matrix to operationalize the environment required for hierarchical decisionmaking for graduated crisis budgeting and resource assignment.

As a total system, the MAM™ may be illustrated as follows.

A collectively exhaustive set of mutually exclusive decisions which have been designated as comprehensively reasonable reactions to the problem situation identified; and from which a subset of decision alternatives may be drawn to construct the final solution set.



A set of multiple, competing criterion references which forms the basis for the comparative evaluation of the model alternatives.

The bounded limits vector supplies standards in the form of numerical bounds attached to criterion vectors of constraint matrix.

The condition vector associates an algebraic inequality ($\leq$,$\geq$) or equality (=) with each vector and RHS pair to form a criterion-based constraint.

A set (or series of sets in the case of cyclic optimality) of criterion values in the form of linear terms which provides for the determination of the most optimal (i.e. the 'best') subset of decision alternatives in remediating the identified problem.

The vector portion (coefficients of the left-hand-side) which denote for each of the modeled alternatives (viz., the dependent variables), the value of each particular criterion's measure or influence (viz., the independent variables) related to that same particular alternative. Thus, the coefficients of each term in the linear inequalities represent the specific criterion measure for that particular term (i.e. alternative).

Recall that the use of the coefficient matrix in conjunction with the right-hand-side (RHS) provides the basis for formulating individual subsets of alternatives designated as feasible solutions (based upon the criterion constraints

established through the simultaneous linear inequalities). These subsets of feasible solutions are then analyzed via the objective function(s) for the final determination of the single optimal solution subset.

To enhance the reader's understanding of not only the use of the MAM™ as a highly sensitive and specialized approach to crisis budgeting based upon program funding graduations, but also for viewing the MAM™ framework as a generalized technique for any situation which is data-based and includes discretely defined alternatives, subsequent sections will note those attributes of the crisis budgeting MAM™ formulation which represent marked deviations from the conventional MAM™ formulation as well as why such deviations were necessary.

STRUCTURE OF THE ALTERNATIVES VECTOR

The alternatives vector is a nominal vector, defining the hierarchical structure of the model, and naming each of the dependent variables (levels of budgeting variance) available for evaluation and comparison. For the graduated budget reduction model, the structure of the alternatives vector is typically of two indices, the first naming the program being modeled, and the second defining the alternative funding variances associated with each type of variance available for consideration. Since this model is variable-level hierarchical, the lower-order options will typically differ by both number and type.

Alternative-j (j=1,...,n) ==> Program/Project Budget Requirement			
Inc Opt(s)-r (r=1,...,R)	0-Opt	Dec Opt(s)-s (s=1,...,S)	*-Opt

Structured Budgetary Increase (Inc) Option which targets the program for a specified increase (in terms of a percent of current funding level) based upon the estimated impact of such an increase to the program's future operations in particular and to the organization as a whole

Program Termination (*) Option which targets the program for discontinuance and its budget for future absorption within the organization

Structured Budgetary Decrease (Dec) Option which targets the program for a specified decrease (in terms of a percent of current funding level) based upon the estimated impact of such a decrease to the program's future operations in particular and to the organization as a whole

Budget Stasis or Zero (0) Option which targets the program for continued funding at the current level of budgetary requirement

such that:

(1) R (number/type of increases in funding options) $\geq$ 0;

(2) S (number/type of decreases in funding options) $\geq$ 0;

(3) R not necessarily equal to S; and the

(4) 0-Opt and *-Opt options considered as comprehensively reasonable across all programs.

The determination of both the number and type of lower-order decisional alternatives in the graduated budget reduction model is a coterminous product of constructing a program options (funding level) scenario (viz. narrative) for each of the alternative levels of budgetary increase or decrease which seem

reasonable based upon the specific, individual attributes of each program. Thus, an expanded view of the alternatives vector may be seen as follows.

Alternative (j)				Alternative (j+1)			
Inc Opt(s)	0-Opt	Dec Opt(s)	*-Opt	Inc Opt(s)	0-Opt	Dec Opt(s)	*-Opt

Increase(s) ..... Decrease(s)

Options for budgetary variances need only be included in the model if such options are available to the decisionmaker. If no option(s) for funding increases or decreases are possible, the respective parts of the model should be eliminated.

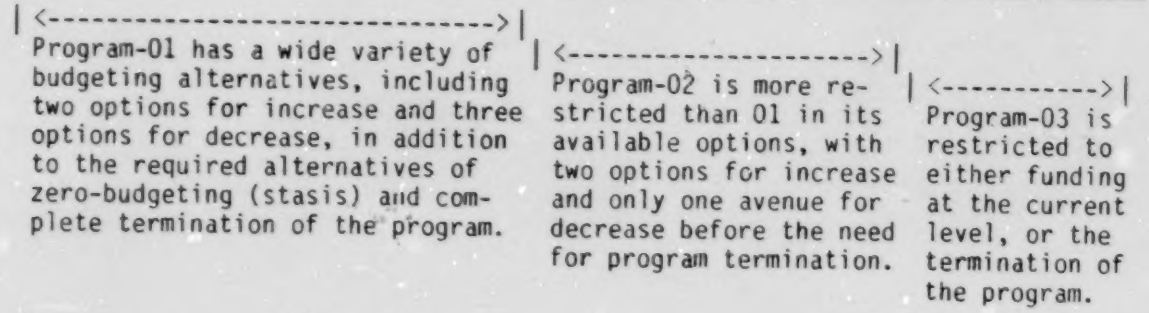
Stasis ..... Term

Although stasis-budgeting and/or program termination may not be reasonable alternatives for the particular model, they must remain as feasible options. In this way, the model can more appropriately evaluate the full range of alternatives available to decisionmakers.

Stasis (i.e. 0 percent variance) and program termination (i.e. 100 percent reduction) must be considered reasonable program funding options for each and every program under evaluation. Although some programs may, whether socially or politically, be ultimately funded at a level inconsistent with the model's recommendations, the decisionmaker has the ability to at least initially survey a more objective interpretation of the data/information modeled during the decisioning simulation. Techniques are also available to force the model's consideration of a certain level of funding variance for a particular program, and thus include any negative as well as positive (beneficial) aspects of such a forced decisional selection upon the remaining more model-dependent options for other program budgets.

A more specific example of the way in which an alternatives vector would be formulated may be illustrated as follows.

Prog-01							Prog-02					Prog-03		...
+12	+03	0	-05	-12	-23	*	+07	+03	0	-15	*	0	*	...


Program-01 has a wide variety of budgeting alternatives, including two options for increase and three options for decrease, in addition to the required alternatives of zero-budgeting (stasis) and complete termination of the program.
Program-02 is more restricted than 01 in its available options, with two options for increase and only one avenue for decrease before the need for program termination.
Program-03 is restricted to either funding at the current level, or the termination of the program.

Whether increase, decrease, stasis or termination, the number and type of funding level alternatives are based upon pre-organized information which identifies the characteristics of each such funding variance in terms of resulting program attributes. This description of the 'future' program under 'future' funding is known as the program options scenario, or funding level narrative.

THE PROGRAM OPTIONS (FUNDING LEVEL) SCENARIO

Although the program options scenario is not a "technical component" of the model itself, the development of a scenario or narrative for each of the lower-order funding decision options should be viewed as extremely important. Since it is highly unlikely that a model could be effectively designed in the absence of knowledge contained in the components of a scenario itself, the development of such a document is simply the transformation into writing of what the alternatives vector represents to the model builder.

The program options (or funding level) scenario is a narrative-based document which explains each of the alternative (lower-order hierarchical) budgeting graduations which will be evaluated for each of the alternative (higher-order) educational programs, whether instructional, service or administrative. For example, a program which has been identified to have four funding increase

and three funding decrease options, as well as the normal stasis and termination options, will have a total of nine (9) individual narratives associated with the program.

The narrative should be construed as having two general parts. The first section, or general program description section, should declare the intended mission and supporting goals (including objectives and activities) of the program. For most cases, this section will largely comprise the first section for each of the variant funding levels being described (viz. narrated) for a particular program. Depending upon the extent of the alternative funding increase or decrease, it might be expected that some goals (or objectives, etc.) will be added or subtracted, respectively, based upon the anticipated budget.

The second section, or program operational variance section, discusses the positive and/or negative influences (e.g. effectiveness, efficiency, satisfaction, economy, etc.) linked to the specific funding increase or decrease associated with that lower-order hierarchical alternative. Typically, this section will discuss the impact to the program, and therefore the program's intended services, which the increase or decrease in funding would herald. In most cases, this is best done through the direct identification of goals (or objectives, etc.) which would be beneficially enhanced or deleteriously effected due to the proposed alternative funding variance.

Consider a program (lower-order hierarchical) alternative in a graduated crisis budgeting model constructed as follows:

Program-01						
+12	+03	00	-05	-12	-23	*

where the suggested alternatives comprise two funding increases (12 percent and 3 percent, respectively), three funding decreases (5 percent, 12 percent and

23 percent, respectively), and the normal variances of stasis (funding at current level to be continued) and termination (100 percent decrease in funding and discontinuance of the program in the future).

A total of seven (7) program options scenarios would be constructed for this example, where the 'general program description' section will describe the general attributes of the program as a whole, and the 'program operational variance' sections identifying the anticipated differences in program activities based upon the associated increases or decreases in funding. In this example, therefore:

Prog-01						
+12	+03	00	-05	-12	-23	*

<== GENERAL PROGRAM DESCRIPTION

<== PROGRAM OPERATIONAL VARIANCE(s)

the mission, supporting goals and objectives, and corresponding activities of program 01 will comprise the general program description. The intent here is to describe the program, narrating the program's current level of functioning, and the extent to which this current functioning fulfills the intended mission of the program's reason for existence. Each of the six (6) narratives describing anticipated program operational variances (enhancement or decline) based upon funding differences will describe what the program will 'look like' if such funding variance is chosen as (part of) the final solution to the current fiscal crisis.

The reader should recognize that such a narrative description (or scenario) should not be difficult, since the program had already been studied to the extent that certain changes (e.g. resulting in 5, 12 and 23 percent decreases in funding) have been previously identified. Therefore, the 'options' scenarios are a sine qua non part of the model albeit less-than-technical component of the mathematical system itself.

STRUCTURE OF THE CRITERIA VECTOR

The use of the term 'criteria vector' can cause some initial confusion, as the model builder attempts to discriminate between the column vector of criteria labels which define the rows of the coefficient matrix, and the actual rows of the coefficient matrix, themselves row vectors of measures which associate the value for each particular criterion to each specific alternative (column of the coefficient matrix). Normally, this confusion is more distracting than consequential.

The criteria vector defines (1) the type or focus of each criterion which is to be used to control the evaluation, comparison and selection from among all available alternatives, and (2) the specific row of the coefficient matrix which will contain these criterion values, important for the proper matching of the corresponding condition(s) and bound(s) in the RHS (right-hand-side). We will attempt in this section of the paper to illuminate the purpose and structure of the criterion vector as a vector of values (worth, detriment, etc.) which will ultimately be used to constrain the selection of a subset of alternatives, and their subsequent identification as feasible and/or optimal, from the existing set of alternatives in the alternatives vector.

Overview of the Criterion Reference. The worth of any criterion lies in its ability to provide direction to the selection of likely alternative actions which are both (1) feasible as potential solutions and then (2) cross-comparative (between feasible alternatives) so that the best (optimal) alternative can be identified and selected as the final solution. In the graduated budget reduction model, all criteria are necessarily expressed as numerical quantities. This does not preclude the use of non-numerical categories of criteria, since numbers can also define nominal measures (classification variables) for introduction into the model.

It is beyond the scope of this paper to discuss in detail the technical aspects of measurement associated with criterion vector identification, design, development and construction. However, without such information the reader's

grasp of the multiple alternatives" method in graduated funding assigments may be significantly precluded. Therefore, we will explore this subject briefly as an attempt to optimize what should be understood versus what should be accomplished in a paper of this length.

Consider the following diagram.

THE CRITERION REFERENCE

A quantitative measure of direction and extent which, for each identified decision alternative, provides a value of genus and species origin to each of the defined comparative standards for the evaluation of multiple alternatives.

CONSIDERATIONS OF CRITERION DEFINITION

(Content)

Genus

1. effectiveness
2. efficiency
3. satisfaction
4. expenditure

Species

1. intent
2. method
3. value
4. means

(Process)

Measurement

1. physical
2. transformational
3. definitional
4. synthetic

Scaling

1. nominal
2. ordinal
3. interval
4. ratio

CONSTRAINED DECISION-MAKING

The comparative evaluation of alternatives across measures of select criterion references, whereby the criterion measures constrain or restrict entry of particular alternatives into the final solution (decision) set.

THE CRITERION CONSTRAINT VECTOR

The utilization of additive vectors of the form:

$$a_{i1} + a_{i2} + a_{i3} \ldots + a_{ij}$$

(a_{ij} represents the specific value of the i-th criterion for the j-th alternative).

FORMULATION OF TH COEFFICIENT MATRIX

Basically, this diagram represents the criterion vector as the row-wise component of the coefficient matrix, whose sole function is to provide values upon which the model can constrain (i.e. direct and control) the comparative evaluation of the available alternatives. What is important to note is that the measures comprising the vectors may be physical (directly able to be measured by a reliable device or means), transformational (a ratio or composite of physical measures), definitional (a concoction of physical measures which purports to value some criterion not directly measurable by conventional means), and synthetic (the introduction of data of variable reliability, e.g. survey data) into the model. These four types of data may be entered into the model with numerical scales of either nominal, ordinal, interval or ratio gradient.

Whatever the type of data, and its supporting measurement scale, the vector of criterion values must be additive,

$$a_{i1} + a_{i2} + a_{i3} + \ldots + a_{ij} \dashrightarrow \text{sum } (a_i \text{ across values } j=1,\ldots,n)$$

i.e. have the ability to produce a sum which represents a composite value of several alternatives (the sum of their criterion values) interacting within the model as a whole. The ability to produce an additive composite measure is all important to the subsequent ability of the model to produce a solution which is reliable based upon the model's design.

With this in mind, we will now explore more specifically some of the typical criterion references which might be incorporated into a graduated budget reduction model for program-based resource allocation in higher education.

Measures of Estimated Expenditure or Economy. To perform program funding related decisionmaking the model must obviously have access to cost data related to each of the various program increase, decrease, stasis and termination alternatives. Typically the costs related to each option will reflect required funding levels for each program, not the amount saved if a particular option is chosen. Such a convention allows the modeler to address increase alternatives the same way as decrease alternatives. In addition, costs related to any program can be categorized by type, account and/or responsibility. Therefore,

several criteria related to costs should be modeled, each relating to a different type (account, etc.) in order to discriminate adequately between variable cost categories. Such breakdowns allow the decisionmaker to later restrict (or relax) select, individual cost criteria without indirectly affecting other categories of expenditure.

Some of the more typical criterion references related to estimated expenditure and/or economy are:

> projected amount of budgetary allocation assignable to each program scenario under review, by appropriate line item, or fund account, responsibility or focus of activities
>
> expected amount of facility release, potential for leasing option of released facilities, and the likelihood for the reassignment of specialized equipment and materials

Expenditure criteria should be modeled in both raw (e.g. dollars) as well as normalized (e.g. T-scores) data formats. As mentioned previously, raw formats allow the model to specifically control for actual dollar-expenditures which is necessary when the model must produce solutions which do not surpass the anticipated total budget of the university (or college, etc.). Normalized formats help the model control for 'relative to central tendency' comparisons. With normalized measures, the comparison between alternatives are expressed in deviations from the mean regardless of the actual high (or low) cost of the programs being evaluated.

Measures of Historical and/or Forecasted Effectiveness. The appropriate evaluation, comparison and selection of program funding alternatives can not be accomplished without addressing the past, current and future effectiveness of each program option. Obviously, high cost programs if also superiorly effective should be perceived by the model as a relative benefit to the organization, in contrast to low cost programs which might be marginally effective or even progressively obsolescent. Effectiveness can be measured in many ways, depending upon the particular goals and objectives of the program. Enrollment trends, accreditation reports, and faculty reputations might all be viewed as acceptable measures of program effectiveness.

Some typical criterion references associated with program effectiveness might be stated as:

> projected positive and/or negative impact to the entire university (including colleges, school etc.) mission related to each of the potential program reductions
>
> extent to which each program scenario is in conformity with established university (etc.) policies and related goals

Effectiveness measures should also be introduced within the model in both raw and normalized formats, although normalized measures are more often the rule. An interesting case in point is when the model builder does not wish to express a raw standard to distinguish between 'what is effective' and 'what is ineffective', but rather compares measures for their relative deviation from the 'average effectiveness measured across all programs being compared'.

Measures of Comparative (Pairwise) Efficiency and/or Satisfaction. Measures related to program efficiency and satisfaction will typically involve pairwise combinations among available alternatives. Such an approach may be necessary because the determination of 'what is efficient' and 'what is satisfying' might only be possible when the question 'as compared to what' is likewise made. Other criteria (e.g. effectiveness) do not often fall into this pairwise categorization since policy standards typically state 'what is to be considered effective' (or at least organizational policy should).

Some criteria related to the categorical measures of efficiency and satisfaction are:

> projected personnel losses, reassignments, transfers or surpluses resulting from each potential reduction
>
> types of program interdependencies which exist based upon the correlated roles of dependent district programs

To illustrate this pairwise comparison strategy, view a criterion whose purpose is to compare the efficiency of the alternative 'program 01, 12% decrease'

with the alternative 'program 01, 5% decrease' or even with the alternative 'program 01, 7% increase'. Do not fall into the trap that presupposes an increase in expenditure automatically results in a corresponding increase in efficiency, or alternatively that decreased funding can stabilize effectiveness through austerity actions of increased efficiency.

Measures of efficiency and satisfaction almost always involve surveying an individual's perceptions or feelings, and accepting the problems inherent in the varying reliability associated with these measures. Such data is typically known as synthetic, and will be dealt with in the following section.

Measures of Differential (Population-based) Perception. Measures of perception (or feelings) can (and should) be utilized in the budget reduction model, although the modeler must control as much as possible for the unreliability characteristics of such 'tell me what you think' measurements. The modeler must recognize that the model does not differentiate between data based upon the extent of the data's reliability, but rather treats the data as if it were perfectly reliable (and valid) in every way.

Examples of differential perception measures which might be utilized in the graduated budget reduction model are:

> surveyed management, staff, faculty and community attitudes towards each type of scenario which might result from each of the potential reductions
>
> projected positive and/or negative impact to each of the remaining university (college, school, etc.) programs based upon the potential program reductions under study

A second issue which must be addressed when modeling perceptual data is that of additivity, that is, the ability of individual data elements to be added and produce a sum which is meaningful as a composite measure. This issue will be addressed in greater detail in a later part of this paper.

Measures of Internal Modeling Control. Like many decision simulation models which are hierarchical and variable level, the model itself does not automati-

cally discriminate between the various funding variance options within one program and similar options within another unrelated program. In addition, the model must be specifically 'told' that one and only one funding option must be selected as a solution for each particular program, and furthermore that no program should be excluded during this process. What may seem like a formidable task to the novice programmer is actually the easiest part of criterion development during modeling formulation.

Although the modeling of these internal decisional control elements will be discussed later in this paper, the reader can view such criteria as follows. Suppose program 01 has a total of seven program options available for evaluation, and of course the model must select one and only one. To accomplish this, a criterion vector must inform the model that seven options are available but that only one must be selected finally. Another vector might link certain lower-level options of different programs together in order to compare certain programs which have something in common (e.g. potential for inservice as well as preservice graduate training). These control-criterion vectors are simply composed of the element '1' and posited in the vector wherever an alternative must be addressed by the model, and therefore wherever other alternatives are to specifically ignored.

Consider the following simple example, where the seven options of a particular program vie for selection, but from which only one option must be chosen as the final solution. Such a control vector would appear as follows:

	opt1	opt2	opt3	opt4	opt5	opt6	opt7	
(control criterion)	+1	+1	+1	+1	+1	+1	+1	= +1

informing the model that all seven options are to be considered, but one and only one alternative must be selected as the final solution.

To better understand this use of a single vector, and its relationship to the other criterion vectors which will ultimately and simultaneously constrain the final selection of the 'total solution', we will now explore the next com-

ponent of the multiple alternatives modeling™ framework, the design and development of the coefficient matrix.

STRUCTURE OF THE COEFFICIENT MATRIX

The function of the coefficient matrix is to store the entire set of criterion values across all program options (decisional alternatives), and to make these values available to the model during execution as needed. Rows of the matrix are defined by the individual criterion focus while columns are defined by each of the options being evaluated. The coefficient matrix of criterion values across all alternative options is the only matrix in the multiple alternatives model™. This unfortunately leads to some amount of dissonance when the component called the constraint matrix is addressed.

The constraint matrix, explored in greater detail later in this paper, is simply the merger of the coefficient matrix with two column vectors known as the condition vector and the bounds vector (together called the right-hand-side). The coefficient matrix can not constrain the decisional process without the addition of these two vectors. The coefficient matrix does however contain the values for each criterion across all alternatives -- these values referred to as coefficients because of their placement in the resulting algebraic inequality or equation -- thus the rationale for the matrix's name.

Because the coefficient matrix can be partitioned into submatrices (i.e. parts of the whole matrix), and each part or submatrix named to represent the type, format or purpose of its criterion components, we will in this paper explore the function of the coefficient matrix in terms of an arbitrary partitioning of the coefficient matrix into submatrices according to data format. Partitioning is cosmetic only, and does in no way lead to a more efficient or effective model formulation as far as the model is concerned. The model developer typically partitions in order to quickly identify certain matrix parts for later data modification during the search for initial feasibility and the later need to relax or restrict certain model constraints. More on this later.

Structure of Criterion-based Data Entry. Criterion values for each program option are entered into the coefficient matrix in much the same way as Christmas

ornaments are stored in their sectioned container -- one ornament for each section, although some sections may be missing an ornament due to breakage or its otherwise being lost. What may seem trite or trivial to the reader is hardly the case in model development. Obviously, only one value for any given criterion can reflect the worth for any given alternative. If several values are existent, then either additional criterion vectors (rows of the coefficient matrix must be constructed) or some composite measure entered into the cell of the coefficient matrix (usually the mean or the sum, depending upon the intent of the criterion and the physical measure itself) as a composite value for the criterion.

Let us view the composition of the coefficient matrix in the form of a mathematical system of appended row vectors.

	Multiple Decision Alternatives (X_j)						
Criteria (A_i)	X_1	X_2	X_3	X_4	X_5	...	X_j
<- Criterion A_1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	...	a_{1j}
<- - Criterion A_2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	...	a_{2j}
<- - - Criterion A_3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	...	a_{3j}
.	.						.
.	.						.
.	.						.
<- - - - Criterion A_i	a_{i1}	a_{i2}	a_{i3}	a_{i4}	a_{i5}	...	a_{ij}

---> $a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + a_{15}x_5 + \ldots + a_{1j}x_j$

------> $a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 + a_{25}x_5 + \ldots + a_{2j}x_j$

---------> $a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 + a_{35}x_5 + \ldots + a_{3j}x_j$

<----------> $a_{i1}x_1 + a_{i2}x_2 + a_{i3}x_3 + a_{i4}x_4 + a_{i5}x_5 + \ldots + a_{ij}x_j$

where:

A_m represents each of the criterion available for evaluation modeling; i = 1,2,...,m criteria.

X_n represents each of the decision alternatives to be modeled with the multiple alternatives framework; j = 1,2,...,n decision alternatives.

a_{mn} represents criterion measures for each of the A-criterion across each of the X-alternatives; i = 1,2,...,m criteria; j = 1,2,...,n alternatives.

$a_{mn}x_n$ represents each cell entry within the constraint matrix wherein the i-th criterion value associated with the j-th decision alternative is defined.

Note how each cell entry in the coefficient matrix represents the coefficients in a vector whose range of dependent variables are the alternatives (columns of the matrix) being compared for membership in the solution set. The dimensions of the coefficient matrix will always, therefore, be m-rows deep where m represents the number of criteria being modeled, and at least n-columns wide where n represents the number of alternatives being compared. Depending upon the decisional situation, the coefficient matrix might be n+k columns wide where k represents the number of 'slack' dependent variables constructed to perform more complex comparisons between separate 'groups' of the dependent 'program options' variables. By extension, the dimensions of the constraint matrix will always be n+k+2 columns wide where $k \geq 0$ and the two (2) additional columns represent the condition and bounds vector of the RHS respectively.

The Raw Data Submatrix. Some number of rows in the coefficient matrix will contain raw values of respective criteria, and is therefore called the raw data submatrix. The raw data submatrix requires greater care in the design of the bounds vector of the RHS; therefore, this submatrix is typically small and is utilized only as absolutely necessary. Such differential use, of course, depends upon the type, format and purpose of the particular criterion being modeled. For the graduated budget reduction model, the raw data submatrix will be nearly exclusively composed of the cost ($$$ expenditure requirements) data. Other criterion measures which may find residence here are enrollments, full-time personnel equivalences, and measures of duration (time).

From the standpoint of data formats and/or types, all physical, transformational and definitional measures, in raw data form, could be contained within this particular submatrix.

The Normalized Data Submatrix. Introduced for the first time in a multiple alternatives modeling™ formulation for school closures (Wholeben, 1978), the use of normalized measures for comparing and contrasting potential decisions plays a significant role in solution membership construction for the graduated budget reduction model. Entries in the normal data submatrix are either z-score or T-score transformations of original raw data distributions, although T-scores are recommended to minimize the necessity for negative numbers and fractional entries. Normalized data allow the model to compare alternatives based upon their relative deviation from computed central tendencies in the alternatives' composite distributions. For the budgeting model, this allows the model to compare and contrast alternatives which may not be the most desirable but which are the only options available. While this same intent could be accomplished through the raw data submatrix, the establishment of the appropriate bounds in the RHS is tedious for raw data, and oftentimes experimental at best.

This particular submatrix can contain normalized transformations of the physical, transformational and definitional raw data measures, and could if additivity is assured also contain normalized transformations of appropriate synthetic data sets. More on this later.

Contrasting the Raw and Normalized Data Submatrices. To better understand the differences between the use of raw data versus normalized measures, we will jump ahead in our discussion to material more appropriately addressed in the sections, Structure of the Right-Hand-Side (RHS) and Structure of the Constraint Matrix. We will contrast the raw and normalized data submatrices here, and review this material again for the reader in these future two sections.

The significant increase in modeling flexibility attributed to the use of normalized over raw data measures lies in (1) the model's ability to compare and contrast alternatives due to relative deviations from a distributional central tendency and (2) the standardization of bounded value assignments in the bounds

vector of the right-hand-side of the constraint matrix. As mentioned previously, normalized coefficients allow the model to select from alternatives which may not be the most desirable, and may even violate established policy, but which are the only alternatives available and represent the institution's best attempts at compliance. The use of normalized coefficients in such a situation can save literally hours of model development and testing time when compared to the raw data approach. Secondly, the choice of appropriate bounds or limits for the RHS of the constraint matrix -- those summed composites which guide the final choice of a solution from among the multiple alternatives available -- can now be a standardized procedure equivalent for all criterion vectors which employ normalized measures as their coefficients. This is easily demonstrated utilizing the following two charts.

For T-normalized scores (preferred):

T-normals for MIN constraint (RHS => n*(50+10) or [n*60])
" " MAX " (RHS => n*(50-10) or [n*40])

where: '50' and '10' are the mean and standard deviation of the T-normal distribution, respectively, and 'n' is the number of programs being evaluated.

---

and, for z-normalized scores:

---

z-normals for MIN constraint (RHS => n*(0.0 + 1.0) or [+n])
" " MAX " (RHS => n*(0.0 - 1.0) or [-n])

where: '0.0' and '1.0' are the mean and standard deviation of the z-normal distribution, respectively, and 'n' is the number of programs being evaluated.

Thus, for a situation in which 200 individual programs were being compared (regardless of the number and/or variety of their lower-order options), the

bound(s) in the RHS for all criteria which are to be maximized would be either '8000' (i.e. 200*(50 - 10)) for T-scores or '-200' (i.e. 200*(0.0 - 1.0)) for z-scores. Alternatively, the bound(s) in the RHS for all criteria which are to be minimized would be either '12000' (i.e. 200*(50 + 10)) for T-scores or '+200' (i.e. 200 * (0.0 + 1.0)) for z-scores. The length of one (1) standard deviation is subtracted from lower bounds and added to upper bounds simply to allow somewhat greater flexibility (relaxation) for the model's comparison and contrast of the alternatives.

The above discussion raises the interesting issue as to the determination of the RHS bounded value for an identity vector (constraint). Very simply, it is not recommended that you employ normalized identity bounds for identify vectors since it adds nothing to either the effectiveness nor efficiency of the model, whether in development or execution. Identity constraints are more typically utilized in the control submatrix, to be discussed in the next section, and employ raw data rather than normalized coefficients.

The Control Submatrix. Controls established in the control submatrix are usually of two types. The first and most typical is that of a series of '1' elements specifying which of the program options are to be evaluated and how many alternatives (in quantity) should be contained in the final solution. This is best illustrated through an example. Consider the situation of five (5) higher-level programs with three, two, four, three, and two lower-order options, respectively. To assure that one and only one option is selected per each of the programs being evaluated, the control submatrix would appear as follows:

1.1	1.2	1.3	2.1	2.2	3.1	3.2	3.3	3.4	4.1	4.2	4.3	5.1	5.2	RHS
1	1	1												=+1
			1	1										=+1
					1	1	1	1						=+1
									1	1	1			=+1
												1	1	=+1

where the bounds entry in the RHS would necessarily be '= +1' for each row of the coefficient (control) submatrix displayed above.

The second type of control established in the control submatrix of the encompassing coefficient matrix typically uses a raw data vector, and in the specific case of the graduated budget reduction model, the coefficients in this vector are the total costs by program of the programs being modeled. The function of this raw data control vector is simply to assure that whichever programs are funded and at what level does not surpass the limit set by the total available university budget.

The Synthetic Measure(s) Submatrix. The last (typical) partitioning of the coefficient matrix (and therefore the corresponding constraint matrix) is based upon available synthetic data (e.g. from a survey of perception). Synthetic measures can be introduced into the model as interval-approximated measures if and only if the measures are additive. Depending upon the sophistication of the device which produced the measures, and the scientific stringency of the model's consumers, questionable additivity may not be a serious violation of the model's overall integrity. This is very situation based, and needs to be viewed separately based upon the context of the decisional environment.

Synthetic ordinal (and therefore nominal) measures can likewise be introduced into the model with a little ingenuity on the part of the model's designer. Consider the following illustration. A suitable group of individuals has been surveyed and asked to what extent they would agree or disagree with the declarative judgement:

"Such a budget cut would significantly decrease program effectiveness."

for each of three programs of three funding options each, and using the following ordinal rating scale:

STRONGLY AGREE (1)	SOMEWHAT AGREE (2)	SOMEWHAT DISAGREE (3)	STRONGLY DISAGREE (4)

so that a larger number (e.g. '4') represented greater disagreement and therefore a better 'rating' for the proposed cut. In turn, such a measure would be

considered a vector where we would wish to maximize a composite sum, if in fact additivity could be assured.

Let us assume that you compute the median of the responses for each of the three options for each of the three programs,

Program 01			Program 02			Program 03		
0-1	0-2	0-3	0-1	0-2	0-3	0-1	0-2	0-3
---	---	---	---	---	---	---	---	---
Md_1	Md_2	Md_3	Md_4	Md_5	Md_6	Md_7	Md_8	Md_9

and as you attempt to compute a meaningful RHS bound to compare the potential sum of median scores (l=1,...,9) a statistically oriented person states that the sum of median-based scores is meaningless and not allowable. What is a reasonable alternative?

Actually, there are several alternatives. One option is to enter a '1' for each program option which is 'deemed acceptable' based upon an interpretation of the median computed. For example, a '1' might be entered for any option whose median was at least 3.0 or higher. Then, the sum of the '1' entries could be controlled with an appropriate (e.g. =+1) RHS-bound. A second alternative is more comprehensive and does not require such a narrow interpretation.

Consider constructing two criteria vectors, one for indicating the frequency with which the 'somewhat disagree' response was chosen for each program option, and the other for the frequency of choosing the 'strongly disagree' response. Now this part of our synthetic submatrix might appear as:

	Program 01			Program 02			Program 03		
	0-1	0-2	0-3	0-1	0-2	0-3	0-1	0-2	0-3
	---	---	---	---	---	---	---	---	---
's/what disag':	27	12	56	45	23	5	34	53	2
'strong disag':	12	45	2	2	34	49	23	24	57

such that 27 'somewhat disagree' responses were recorded for Program 01, Option 1 as compared 12 'strongly disagree' responses, etc.. An appropriate bound for

the RHS can now be computed according to (1) central tendency, (2) predetermined limits on the 'disagreement' response, or (3) some other arbitrary condition.

We have now explored that component of the multiple alternatives model™ known as the coefficient, and out of necessity introduced you in piecemeal fashion to the use of the condition and bounds vectors. We will now discuss these two vectors in greater detail, especially as to how they might relate to the graduated budgeting model.

STRUCTURE OF THE RIGHT-HAND-SIDE

The right-hand-side is the name given to represent collectively two column vectors which when applied to the coefficient matrix allow the multiple alternatives model™ to perform decisionmaking within a constrained environment. These two vectors, the condition and bounds (bounded limits) vectors, provide the necessary, one-to-one algebraic articulation with the vectors of the coefficient matrix to construct the system of inequalities and equalities which provide constraints to the upcoming evaluation, comparison and selection of a solution from among available alternatives.

Recall the structure of the coefficient matrix. Each row represents a vector of criterion values (coefficients) which purports to assign worth to each of the alternatives (dependent variables) available for comparison and contrast. Depending upon which of the dependent variables are being considered as potential members of the solution set, the dependent variable's corresponding coefficients are added together and compared to some bound or limit, typically a standard established by the policy of the institution. A group of dependent variables is considered feasible as potential solutions if and only if that comparison satisfies the limits established by policy.

This modeling of policy limits is accomplished through the use of the two vectors of the right-hand-side. Initially, however, each separate vector of the coefficient matrix must be defined as one of three possible criterion types: a maximizer criterion, a minimizer criterion, or an identity criterion. Recall that maximizer criteria typically model 'positive' (i.e. benefit) criteria,

minimizer criteria typically address 'negative' (i.e. detrimental) areas of concern, and that identity criteria are most often control elements for the model during execution. Consider the following diagram.

Multiple Decision Alternatives (X_j)

Criteria (A_i)	X_1	X_2	X_3	X_4	X_5	...	X_j
Maximixer <- Criterion A_1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	...	a_{1j}
Minimizer <- Criterion A_2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	...	a_{2j}
Equality <- Criterion A_3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	...	a_{3j}
.	.						.
.	.						.
.	.						.

---> Maximizer Constraint:

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + a_{15}x_5 + \ldots + a_{1j}x_j$$

requires that the sum of the individual criterion cell values be equal to or greater than a specified lower bound as defined by the corresponding row entry within the conditional vector (RHS).

------> Minimizer Constraint:

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 + a_{25}x_5 + \ldots + a_{2j}x_j$$

requires that the sum of the individual criterion cell values be equal to or less than a specified upper bound as defined by the corresponding row entry within the conditional vector (RHS).

---------> Identity Constraint:

$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 + a_{35}x_5 + \ldots + a_{3j}x_j$$

requires that the sum of the individual criterion cell values be equal to a specified parameter as defined by the corresponding row entry within the conditional vector (RHS).

After this initial definition of each criterion vector of the coefficient matrix, the model must then be informed of 'your vector-by-vector definition'. The condition and bounds vectors in the RHS perform this task very efficiently.

The Condition Vector (CV) Component of the RHS. The condition vector is a discrete column vector whose cell entries contain one of the three values: $\geq$, $\leq$, or =. The algebraic inequality condition '$\geq$' defines the vector in the coefficient matrix as a maximizer. This simply means that a 'lower bound', defined in the corresponding entry of the bounds vector (see below), must be surpassed by the computed sum of the vector's coefficients (based upon which of the dependent variables are being considered at the time for solution membership), moreover that the final value of that sum should be as high as possible. A condition vector value of '$\leq$', on the other hand, defines the associated vector of the coefficient matrix as a minimizer. This means that an 'upper bound', also found in the corresponding entry of the bounds vector, must not be surpassed by the computer sum of the appropriate vector coefficients. The level which these sum eventually reach -- high for maximizers and low for minimizers -- depends upon the level of competition existing between the various criterion constraints. A value of '=' defines an identity vector, several examples of which have already been reviewed in this paper.

The Bounded Limits Vector (BLV) Component of the RHS. The bounds vector links with the condition vector to become what is called the right-hand-side or RHS, and which ultimately converts the coefficient matrix into a constraint matrix for alternatives comparison and constrast. A discrete column vector, the BLV has cell entries which are classified as a lower bound, upper bound or identity, depending upon the vector's definition as a maximizer, minimizer or identity, respectively. It is the sole function of the BLV to model policy limits or standards, and to provide the model with a basis for determining whether some subset of alternatives (dependent variables) are feasible (potential solutions) or not. In conjunction with the CV, the BLV establishes each vector of the coefficient matrix as either an inequality or equation. Now a system of linear inequalities and equalities, the model is prepared to begin its sorting and culling of the available alternatives.

It might seem strange that, with all of the technical jargon associated with the various components (vectors, matrices, etc.) of the multiple alternatives model™, the term "right hand side" or RHS is a member of the technical dictionary. It may be the only term which inherently makes sense from genesis.

STRUCTURE OF THE CONSTRAINT MATRIX

The constraint matrix contains the full system of linear inequalities and equalities which will ultimately constrain the evaluation, comparison and final selection of some number of subsets of feasible solutions from among the range of alternatives available, and thus the rationale for the matrix's name. In structure, the constraint matrix is simply the condition and bounds vectors appended to the right-hand-side of the coefficient matrix.

Each row (i.e. vector) of the constraint matrix therefore represents a constraint to the modeled decisionmaking process, decisioning here defined as the selection of feasible alternatives from the set of all available alternatives. The secondary process of choosing the one, best alternative (usually a single subset of alternatives) will be discussed later when we explore the relationship of the objective function to the constraint matrix during model execution. For now, to better understand the structure of the constraint matrix, we offer the following figure.

	Multiple Decision Alternatives (X_j)							Cond Vect	Bound Value
Criteria (A_i)	X_1	X_2	X_3	X_4	X_5	...	X_j		
Maximixer Criterion A_1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	...	a_{1j}	(lower bound) $\geq$	b_1
Minimizer Criterion A_2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	...	a_{2j}	(upper bound) $\leq$	b_2
Identity Criterion A_3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	...	a_{3j}	(identify bound) =	b_3
.	.						.	.	.
.	.						.	.	.
.	.						.	.	.

---> Maximizer Constraint:

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + a_{15}x_5 + \ldots + a_{1j}x_j \geq b_1$$

illustrates a constraint whose summation must equal or exceed the value of the lower bound b(1) found within the RHS; Maximizing constraints normally signify criteria of positive effect (i.e. benefit) which attempt to accrue maximum impact to the system based upon the mix of alternatives selected.

------> Minimizer Constraint:

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 + a_{25}x_5 + \ldots + a_{2j}x_j \leq b_2$$

illustrates a constraint whose summation may equal but never exceed the value of the upper bound b(2) within the RHS; Minimizing constraints normally signify criteria of negative effect (i.e. cost) which attempt to limit the amount of negative impact to the system based upon the mix of alternatives selected.

---------> Identity Constraint:

$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 + a_{35}x_5 + \ldots + a_{3j}x_j = b_3$$

illustrates a constraint whose summation must equal (i.e. be identical to) the parametric value b(3) within the RHS; Identity constraints normally signify primary control criteria which delimit the relationship between alternatives and criteria.

The constraint matrix as a system of linear inequalities and equations guides the decisioning process, informing the model that any subset of alter-

natives (dependent variables defined by the columns of the matrix) can be considered feasible (i.e. potentially a solution) if and only if the sum of the alternatives' respective values in each of the constraint matrix's row vectors (i.e. criteria) satisfy the condition and bounds set in the RHS. Therefore, if the constraint matrix contains 20 rows (20 criteria constraining the decisional process), then any subset of alternatives, to be considered as a feasible solution alternative, must produce individual row sums which simultaneously satisfy each of the 20 conditional bounds set in the RHS. The sheer mystique of such a simultaneous process, of course, pertains to the fact that different combinations of the alternatives will produce different sums, and therefore a variable potential for becoming a member of the set of all subsets of feasible solution alternatives.

Determination of the Decisional Space. Like most search, sort and select operations, the multiple alternatives model™ must first determine, from all possible alternative actions (in our case, program funding level options), what combinations of alternatives simultaneously satisfy the constraints established by the constraint matrix. Since each of the constraint vectors of the constraint matrix compete for influence on the choice of what number of alternatives and which ones (when summed) satisfy the RHS, the presence of any particular vector is significant in determining whether a subset of the available alternatives is feasible or infeasible as a potential solution.

The concept of feasibility is sometimes confusing to the novice, since some subsets of alternatives will be termed feasible, others infeasible, and therefore some finite number of subsets of feasible alternatives as alternative feasible solutions, from which a single subset will later be selected as the optimal solution. All possible combinations of alternatives available to the model define what is called the decisional space. Some region inclosed within the decisional space must be defined as feasible, that is, containing those subsets of alternatives which satisfy all constraints. From this region of feasibility a single subset must be identified as optimal. From the mathematician's viewpoint, this is trivial. For the model builder, several hours of effort may be necessary unless care is taken initially.

Search for the Feasibility Region. In the graduated budget reduction model, not only must the budgets of all programs introduced into the model be balanced in the final solution, and therefore in one-to-one correspondence with the overall budget of the university, but moreover all other 'constraints' to the decisioning process must also be 'balanced'. Constraints on effectiveness, efficiency, satisfaction, perception, etc. must all be balanced according to the dictates of the RHS. It is the RHS which partitions the region of feasibility from the decisional space, and identifies each of the subsets of feasible alternatives which are members of that feasibility region. Thus, the RHS provides the clue to determining initial feasibility in the reduction model.

It may be somewhat obvious to the reader, that if the conditional bounds of the RHS are too restrictive and therefore no subset of alternatives can be identified as satisfying all of the constraints in the model, no corresponding region of feasibility exists. Therefore, no solution exists, optimal or otherwise. This presents an interesting (actually nerve-racking) problem. If initial feasibility is not established on the first execution of the model, all the model can do is to simply report "feasibility not established". Unfortunately, the model can not suggest that if the designer will simply raise 'this' particular upper bound, lower 'that' particular lower bound, and change 'some' specific identity bound, an initial region of feasibility might be established. The model is lost, and so are you if you do not know what to do next.

A simple rule of thumb will preclude this difficulty getting out of hand. It may not prevent the problem from occurring initially, but you should be able to establish feasibility on at least the second (or at the most, third) try. The rule:

> Apply extreme relaxation initially in the RHS by constructing very low 'lower bounds' for maximizer constraints, very high 'upper bounds' for minimizer constraints, and being selective in the use of identity constraints. This technique should establish a baseline feasibility region from which you can gradually and individually restrict each of the constraints (by raising lower bounds, etc.) to model adequately and

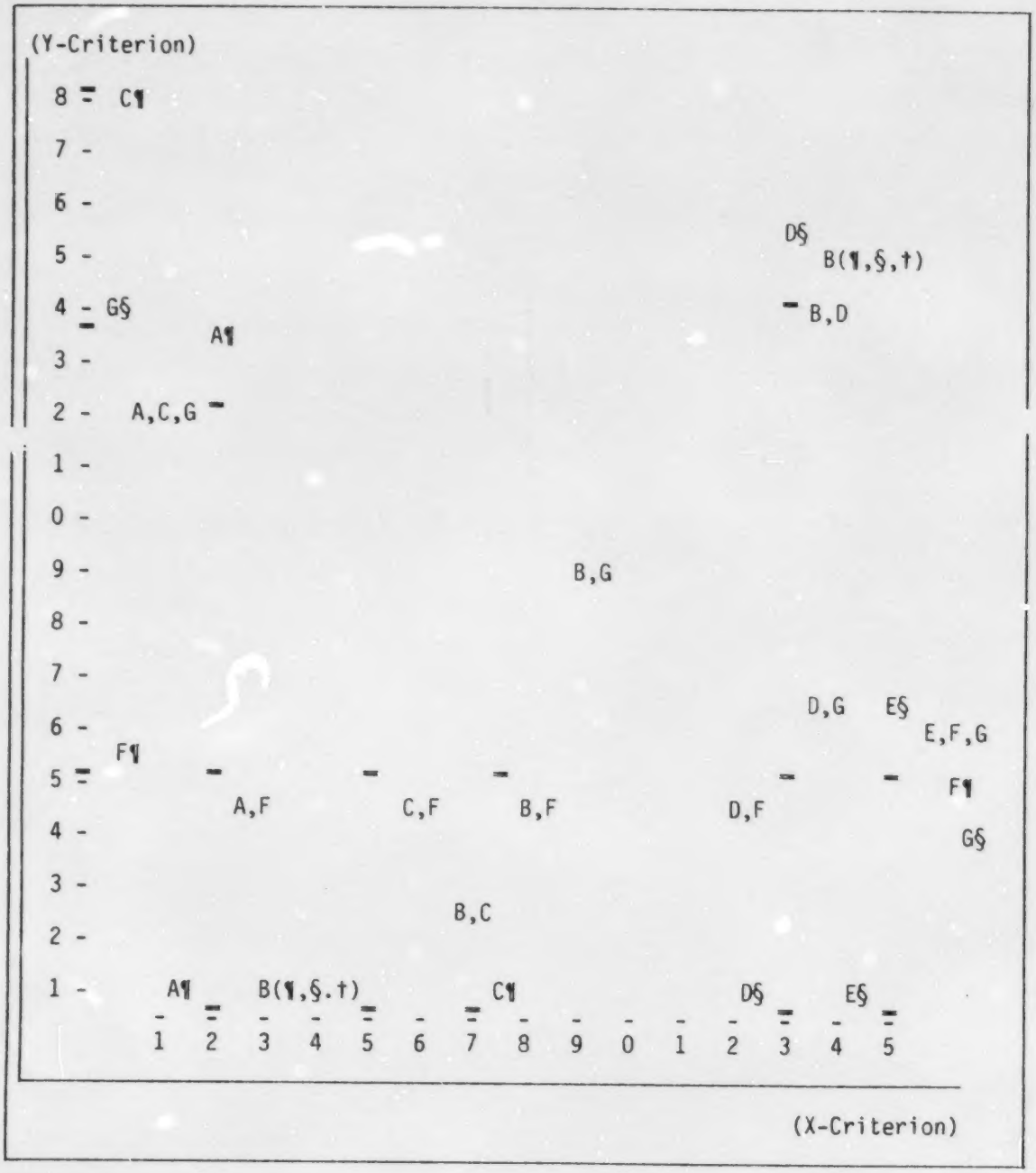
appropriately the situation intended for the model. When infeasibility is once again encountered, it is obviously the result of the last restriction imposed on the model. Relax this restriction to its previous level, and continue restrictions with another constraint as appropriate.

To better understand this procedure, and how it works, let us explore the geometric relationships the model draws upon to do it work.

Identification of Subsets of Feasible Alternatives. Since linear inequalities and equations can be plotted as x-y coordinates (two-dimensional space) when two alternatives are being compared or as x-y-z coordinates (three-dimensional space) when three alternatives are evaluated, it necessarily follows that graphing more than three alternatives is feasible though impractical. To solve this problem for the reader, a technique called composite mapping will be employed. Mapping simply means to construct a visual representation of a mathematical formulation (e.g. the graph of a linear inequality on coordinate graph paper). Composite mapping means to switch the scaling of the graph from the normal dependent/independent variable scales to axes which represent a composite of the functions graphically depicted utilizing these scales.

Normally, a multiple alternatives problem of two alternatives can be depicted on simple graph paper by having the x-axis represent one of the alternatives as an independent variable, and the y-axis represent the other alternative as a dependent variable -- if we allow the value of the alternatives to be scaled as continuous (distribution) variables. This same technique works for three dimensions as well when three alternatives are being evaluated. In our model, the problem is that we wish the dependent variables to take on values of '1' or '0', only, representing their membership or nonmembership in the solution set, respectively. We will circumvent this problem by defining our axes to represent continuous distributions used to scale two criterion constraints in the model. Vector graphs of inequalities and equalities will represent each of the alternatives being compared, the singular influence on each alternative by the two criteria, and each alternative's composite proximity to the region of feasibility.

Consider the following graph, in which seven (7) alternatives are graphically represented by means of the corresponding influences of two (2) criterion variables. Vectors A¶, C¶ and F¶ are defined as representing maximizing constraints, while vectors D§, E§ and G§ are defined as representing minimizing constraints. Vector B(¶,§,†) may take on the constraint qualities of maximizer, minimizer or identity depending upon the dictates of the model developer. All vector intersections identified by the letters A,...,G demonstrate areas where the model has calculated the relative worth of a single alternative, or group of alternatives, for its (their) potential as members of the solution.



(¶ maximizer constraint; § minimizer constraint; † identity constraint)

where:

X-Criterion (Scale Interpretation)

Interval-1			Interval-2			Interval-3			Interval-4			Interval-5		
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
LO	MD	HI	LO	MD	HI	LO	MD	HI	LO	MD	HI	LO	MD	HI

Example: '05' rates the alternative as INTERVAL-2/MEDIUM on Criterion X.

and,

Y-Criterion (Scale Interpretation)

Interval-1			Interval-2			Interval-3			Interval-4			Interval-5			Interval-6		
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
LO	MD	HI	LO	MD	HI	LO	MD	HI	LO	MD	HI	LO	MD	HI	LO	MD	HI

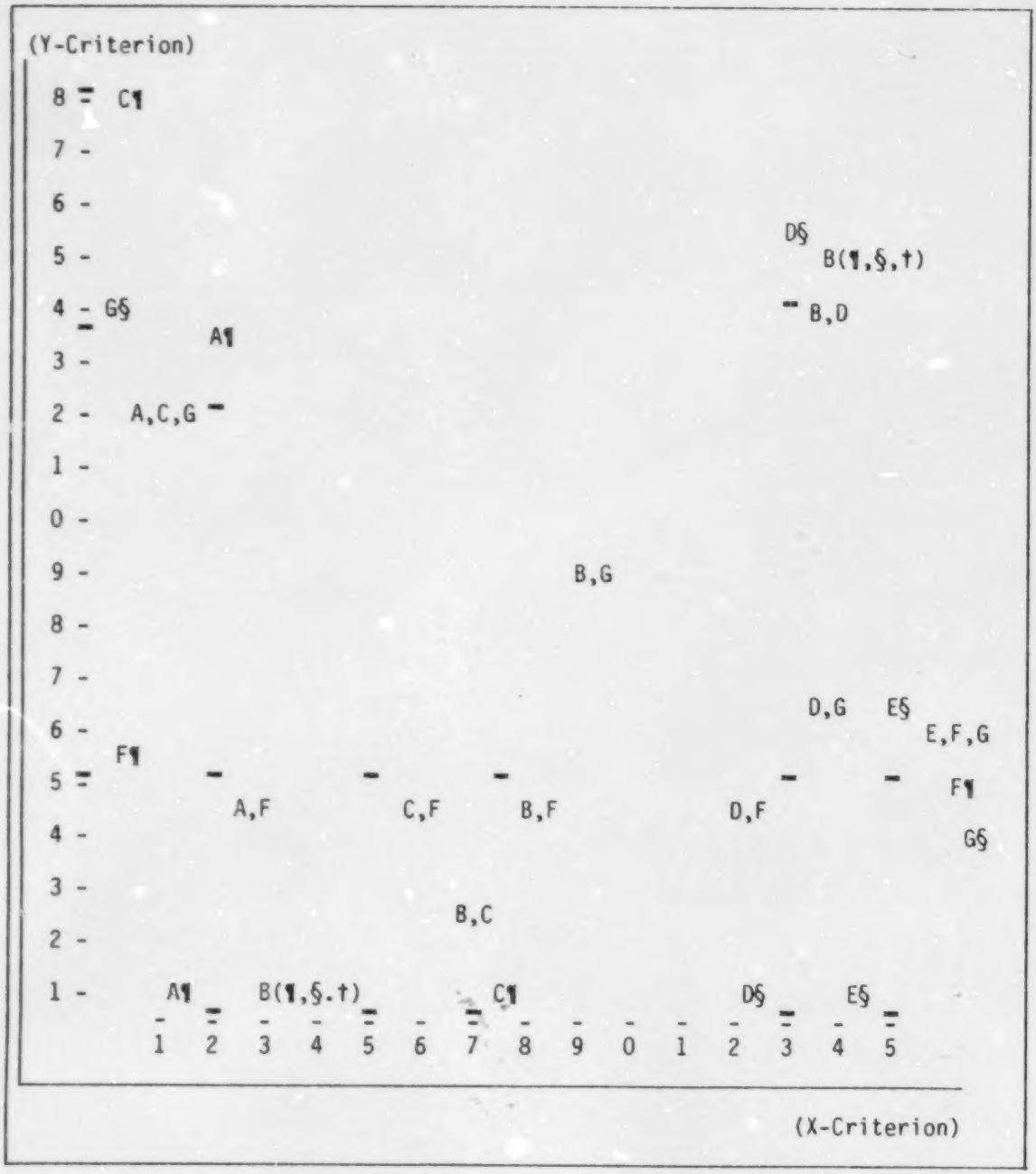
Example: '15' rates the alternative as INTERVAL-5/HIGH on Criterion Y.

Ignoring vector B(¶,§,†) for now, let us assume that the region defined by the vertices [(A,C,G),(C,F),(B,F),(D,F),(D,G),(B,G)] satisfies all constraints represents by the three maximizer and three minimizer constraints. By extension, we can assume that each vertex, any point on any vector bounding this region, and any point within the region bounded by the four surrounding vectors also satisfies all six constraints, simultaneously. This region is the region of feasibility discussed earlier. (See outlined portion of graph on preceding page.) Actually, we need only concern ourselves with the vertices of the bounded region, since mathematical proof demonstrates that only these subsets of identified alternatives will prove to be optimal when the objective function is applied. (We will not concern ourselves with proving this statement here.)

We will now explore the effect upon the existing region of feasibility which the vector B(¶,§,†) will have depending upon whether it is chosen as a maximizer, minimizer or identity constraint. For discussion purposes, we will assume that if B is maximized, then the area to the right of the vector (including all points contained on the vector itself) are feasible. On the

other hand, if B is minimized, then the area to the left of the vector (again including all points on the vector) are feasible. However, if B is identified as an identity constraint, then only the points on the vector line itself can be considered to be feasible, all points to both the right and left of the vector not satisfying the constraint's of equality.

Therefore, if B¶ exists, then the feasibility region is decreased to include only that sub-region defined as [(B,G),(B,F),(D,F),(D,G)]. On the other hand, if B§ exists, then the subsequent feasibility region is decreased to include only the space [(A,C,G),(C,F),(B,F),(B,G)]. What happens if B† exists? With B†, only that part of the original [(A,C,G),(C,F),(B,F),(D,F),(D,G),(B,G)] which is also B† is rendered feasible. Thus, only the points on line [(B,F),(B,G)] can be considered feasible. Therefore, depending upon the condition imposed by B(¶,§,†), the region of feasibility may defined only four, four and two feasible combinations of alternatives, respectively.



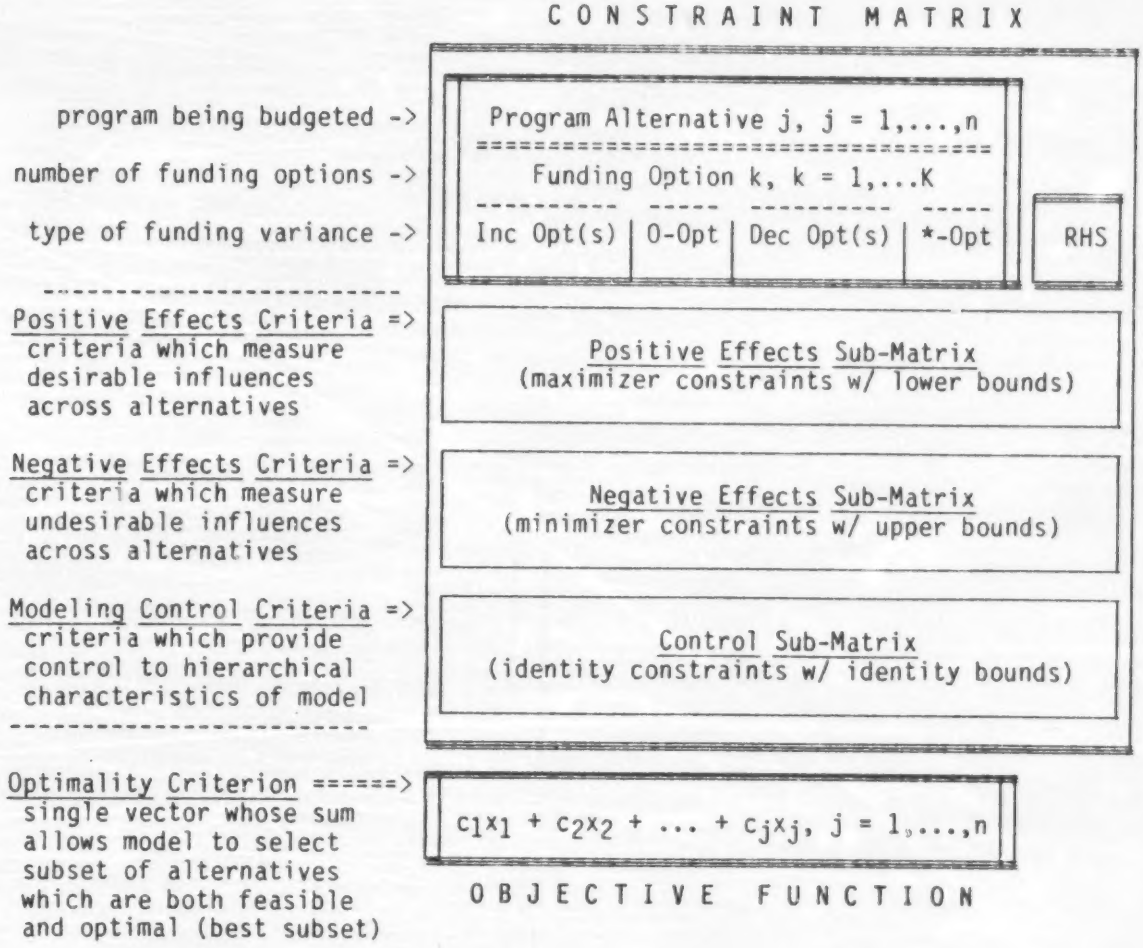
(¶ maximizer constraint; § minimizer constraint; † identity constraint)

Choosing which of these combinations of feasible alternative subsets is, in fact, optimal is the responsibility of the objective function.

STRUCTURE OF THE OBJECTIVE FUNCTION

The last component of the multiple alternatives modeling™ framework, the objective function, provides the model with the ability to choose the one, best solution subset from all subsets of feasible solution alternatives identified by the constraint matrix. The objective function is itself a criterion vector, but without a formal conditional bound reflected in the RHS. The values in the objective function are summed in exactly the same way as are the vector elements in the coefficient matrix during the model's comparison and contrast operations. With no RHS-value attached, the objective function simply attempts to either maximize or minimize its summation. That subset of alternatives which is determined to be (1) feasible and (2) present a sum of objective function entries which is highest or lowest, depending upon whether the objective function is to be maximized or minimized respectively, is considered the optimal solution (subset).

Viewed structurally as part of the MAM™ framework, the objective function completes the model's full design, and can be illustrated as follows.


CONSTRAINT MATRIX
program being budgeted ->
number of funding options ->
type of funding variance ->
Program Alternative j, j = 1,...,n
Funding Option k, k = 1,...K
Inc Opt(s)
0-Opt
Dec Opt(s)
*-Opt
RHS
Positive Effects Criteria =>
criteria which measure desirable influences across alternatives
Positive Effects Sub-Matrix
(maximizer constraints w/ lower bounds)
Negative Effects Criteria =>
criteria which measure undesirable influences across alternatives
Negative Effects Sub-Matrix
(minimizer constraints w/ upper bounds)
Modeling Control Criteria =>
criteria which provide control to hierarchical characteristics of model
Control Sub-Matrix
(identity constraints w/ identity bounds)
Optimality Criterion ======>
single vector whose sum allows model to select subset of alternatives which are both feasible and optimal (best subset)
c1x1 + c2x2 + ... + cjxj, j = 1,...,n
OBJECTIVE FUNCTION

The geometric role of the objective function (sometimes called the optimality vector) is to select which of the vertices of the feasibility region produce the maximum (or minimum) sum, depending upon whether the criterion basis for the objective function is positive or negative, respectively. In two-dimensional space (two alternatives being compared), the objective function is a line passed through the feasibility region searching for a vertex. In three-dimensional space (three alternatives evaluated), the objective function is a plane similarly passed through a region which is solid (three-dimensional). The point at which the objective function (line or plane in these examples) commences to depart the region of feasibility declares either the function's minimum

or maximum value, and thereby the optimal solution based upon the identity of the vertex.

A number of additional issues, however, must first be addressed before leaving this topic, and proceeding to a more specific illustration of a graduated budget reduction formulation in MAM™.

Components of the Singular Optimization Approach. The successful execution of the model needs only a single objective function to guide the final choice from among the varying feasible subsets of decisional alternatives. Therefore, the model developer must recognize inherent problems in the use of an objective function whose cell entries (coefficients) vary only slightly. As the sum of the difference between the computed mean of the coefficients of the objective function and each of these same coefficients approaches zero, the model must rely more heavily upon the maximizer, minimizer and/or identity constraints in the constraint matrix. Several problems do arise if the constraints are unable to significantly discriminate between the identified subsets of feasible alternatives, when the objective function has computed equal sums for several of these alternatives.

The use of a single objective function produces a single optimal solution if a feasible solution exists, all other things remaining equal. In order to produce a second (or third, etc.) optimal solution for comparison to the first, the only recourse is to relax and/or restrict the RHS of one or more constraints. Oftentimes however, this simply produces the same optimal solution as before. To construct a separate optimal solution under singular optimization, the relaxation and/or restriction of constraints results in a model which is neither reasonable nor valid to the problem at hand. The alternative to this dilemma is to employ a cyclic optimization technique.

Components of the Cyclic Optimization Approach. Cyclic optimization employs two or more (typically more) objective functions, executing each in turn, and producing separate results which can be compared and contrasted by various statistical techniques. Research by the author has demonstrated that even the use of some of the criterion vectors in the coefficient matrix (i.e. re-use) can

produce variable optimal solutions which can then be post-hoc analyzed for their reasonableness as an actual final solution for implementation.

The Threat of Multicollinearity. Model builders are wise to run simple correlations among the vector coefficients which will become constraints, and between the criterion coefficients and the coefficients of the objective function. If the coefficients of two (or more) vectors of the coefficients matrix produce significantly high correlations, it would be reasonable to delimit one from further use, or to form a composite of the vectors involved. Multicollinearity within the coefficient matrix is inefficient since highly related values are being modeled together. At worst, such vectors have the potential to produce degenerate solutions.

A significantly high correlation between the objective function and one or more of the vectors of the coefficient matrix introduces decisional bias into the model which may not be intended, or if intended, must be acknowledged.

THE GRADUATED PROGRAM BUDGET REDUCTION MODEL

Our rather laborious and circuitous route will hopefully better enable the reader to understand and accept the complexity and comprehensiveness of the graduated budget reduction model. Precisely stated, this model seeks to:

ASSIGN FUNDING VARIANCES TO ALL BUDGETS WITHIN THE UNIVERSITY (choosing from pre-evaluated funding decrease and increase options, including stasis budgeting and the possibility of full program termination)

subject to:

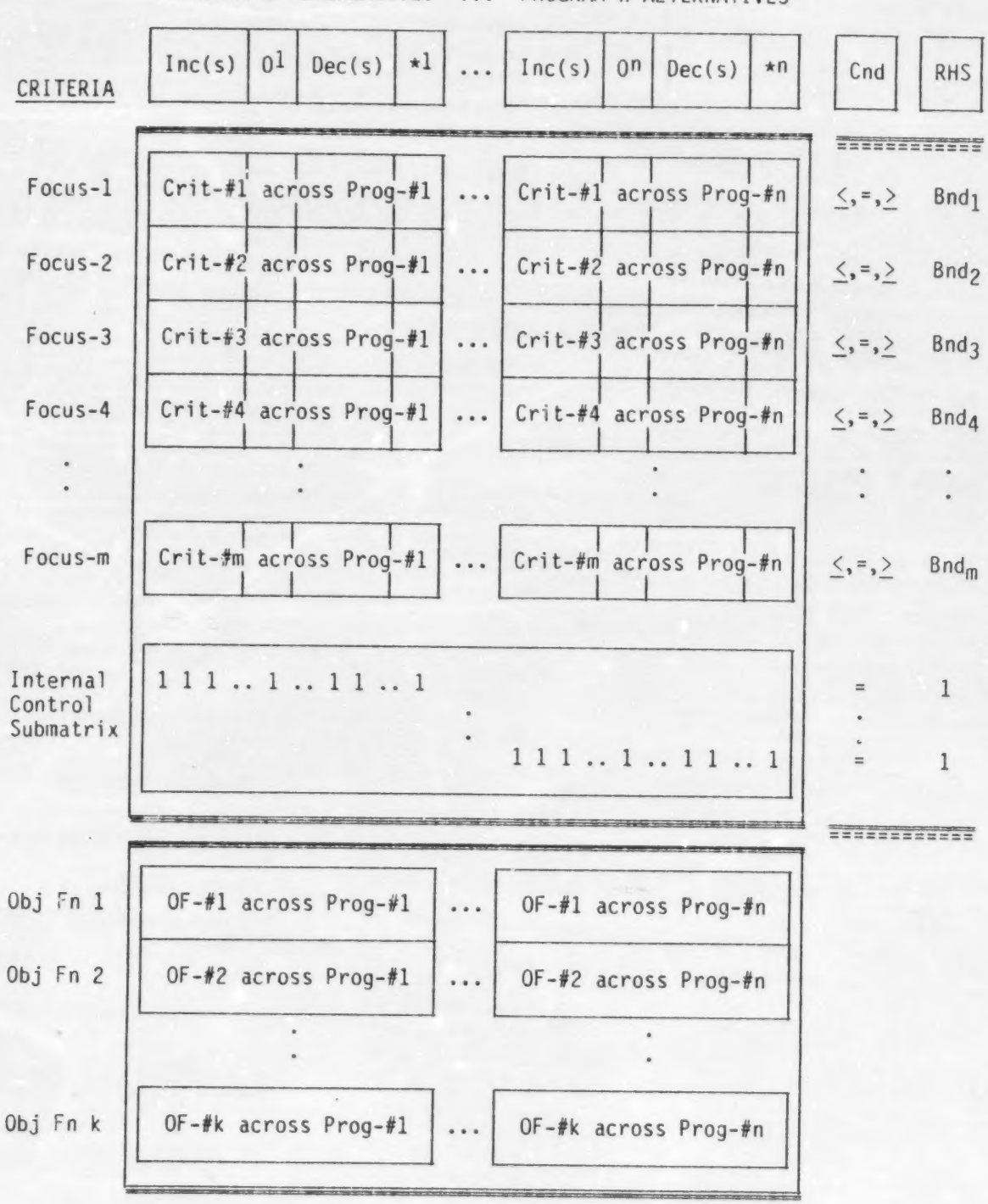
1. maximizing the positive influence from all programs on total university functioning, based upon final program-by-program budgeting levels selected;

2. minimizing the negative influence from all programs on total university functioning, based upon final program-by-program budgeting levels selected;

3. assuring all programs within the university are non-discriminantly evaluated, compared and constrasted to ascertain their contributing value or worth to the goals of the university; and,

4. conclusively targeting levels of funding based upon valid measures of effectiveness, efficiency, satisfaction and economy pertinent to the character of each individual college, school and/or department.

To accomplish this intent, a reformulation of the multiple alternatives modeling™ framework (Wholeben, 1980) for hierarchical decisionmaking has been explored. Within the MAM™ context, each university program is delineated into several funding variant options depending upon a pre-modeling evaluation of each program, and the resulting budgeting (program options) scenarios or narratives which result. Criteria, in the form of numerical vectors, are introduced within the model to (1) depict the pluses and minuses associated with each program budgeting alternative, (2) compete for influence in the comparison and constrast of each funding alternative with other likely options, and (3) simulate the decisional environment of the university, and its various schools and/or departments. This graduated approach to evaluating and selecting funding alternatives based upon merit and estimated impact is MAM™ formulated as follows:


PROGRAM-1 ALTERNATIVES ... PROGRAM-n ALTERNATIVES
CRITERIA
Inc(s) | O1 | Dec(s) | *1 ... Inc(s) | On | Dec(s) | *n
Cnd
RHS
Focus-1 Crit-#1 across Prog-#1 ... Crit-#1 across Prog-#n ≤,=,≥ Bnd1
Focus-2 Crit-#2 across Prog-#1 ... Crit-#2 across Prog-#n ≤,=,≥ Bnd2
Focus-3 Crit-#3 across Prog-#1 ... Crit-#3 across Prog-#n ≤,=,≥ Bnd3
Focus-4 Crit-#4 across Prog-#1 ... Crit-#4 across Prog-#n ≤,=,≥ Bnd4
Focus-m Crit-#m across Prog-#1 ... Crit-#m across Prog-#n ≤,=,≥ Bndm
Internal Control Submatrix
1 1 1 .. 1 .. 1 1 .. 1
1 1 1 .. 1 .. 1 1 .. 1
= 1
= 1
Obj Fn 1 OF-#1 across Prog-#1 ... OF-#1 across Prog-#n
Obj Fn 2 OF-#2 across Prog-#1 ... OF-#2 across Prog-#n
Obj Fn k OF-#k across Prog-#1 ... OF-#k across Prog-#n

The reader should notice that the above depiction incorporates the use of cyclic optimization techniques for model execution. It is the author's view that cyclic optimization is superior to singular optimization (the use of a single objective function during alternatives evaluation) because of the additional information available for comparing and contrasting varying optimal solutions. Statistical techniques are available for performing such post-hoc analyses.

A diagrammatic insert (following this page) symbolically demonstrates the use of a criterion-based focus for modeling mandated policy guidelines (limits) across likely alternative budgeting scenarios. Although only ten criterion foci are modeled across five programs, each with variable-level hierarchical funding options, it is more likely to expect a constructed model to evaluate a hundred or more criterion influences across several hundred program funding alternatives.

Luckily, computer-based analysis programs are available to preclude the necessity for most hand calculations. The author is currently constructing such a computer program which will be interactive and executable on small, readily available microcomputers, such as the Apple IIe.

As previously discussed at length, the criterion based influence within the model allows superior flexibility to the modeler for introducing the effect of certain influences on the final selection of a best-match (optimal) solution. Criteria reflecting measures of program effectiveness, efficiency, satisfaction and economy are able to be input to the model for comparing and contrasting the individual impact of any one program option, and that program's contributing impact to the university. These criterion influences may be based upon physical, transformation, definitional and/or synthetic datum bases, and entered into the model with any one or more of the typical nominal, ordinal, interval or ratio scale formats.

These criteria compete with each other for their influence in selecting the final solution -- a targeted funding level for each program modeled.

Budget Scenario A						Budget Scenario B							BS C		Budget Scenario D						Budget Scenario E				POLICY LIMITS
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
+5	00	05	10	25	**	+7	+6	00	12	19	50	**	00	**	00	03	11	19	25	**	+9	00	10	**	
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Projected budgeting allocation requirements, across budget scenario, by line item, must not exceed																									total university budget
Projected resource requirements (personnel, facilities, equipment and materials) must not exceed																									current university inventory
Ability of the various budgeted programs to competitively supply services which will meet or exceed ...																									projected university needs
Projected negative interrelationships and impact between and among district programs must not exceed ..																									maximum negative impact
Projected positive interrelationships and impact between and among district programs must exceed																									minimum positive impact
Prerequisite and corequisite relationships must be established in order to assure continuance of																									university integrated programs
Administrative, staff, faculty and community perceptions must provide the basis for understanding																									maximum university consensus
Projected personnel losses, reassignments, transfers or surpluses must not exceed an established																									minimum university policy
Extent to which potential program budget reductions and/or terminations conform to various policies ...																									maximize university goals
Each budget scenario must be evaluated and compared, and the final district solution must impact																									each university program

To illustrate this criterion scaling, observe the following figure.

	Budget #1				Budget #2			Budget #3		
	00	15	25	**	00	05	**	00	**	
Personnel	$11	$12	$13	$14	$15	$16	$17	$18	$19	<= $$1
Example:	100	85	75	00	50	47	00	70	00	<= 195
	(personnel costs expressed in $1000 units)									
Personnel	a11	a12	a13	a14	a15	a16	a17	a18	a19	<= ##1
Example:	6.0	4.5	4.0	0	4.0	3.5	0	3.0	0	<= 11.0
	(personnel requirements expressed in F.T.E. units)									
Policy 1.0	a21	a22	a23	a24	a25	a26	a27	a28	a29	>= b2
Example:	4.7	3.6	2.3	1.9	2.5	2.1	1.3	3.9	3.8	>= 9.0

Fails to Meet Most Requirements	Fails to Meet Some Requirements	Marginally Acceptable (Neutral)	Meets Most Requirements as Defined	Exceeds Most Requirements as Defined
[1]	[2]	[3]	[4]	[5]

Policy 2.0	a31	a32	a33	a34	a35	a36	a37	a38	a39	>= b3
Example:	2.4	2.3	1.5	1.1	4.9	4.5	2.3	3.6	1.0	>= 7.5
	(Scores assessed utilizing 5-point continuum displayed above)									
Opinion	a41	a42	a43	a44	a45	a46	a47	a48	a49	>= b4
Example:	5.8	4.7	3.2	2.8	4.7	3.2	3.1	4.3	1.7	>= 16.0

High Negative	Negative	More NEG Than POS	More POS Than NEG	Positive	High Positive
[1]	[2]	[3]	[4]	[5]	[6]

Preference	a51	a52	a53	a54	a55	a56	a57	a58	a59	>= b5
Example:	25	50	10	15	66	33	1	85	15	>= 198
	(Data represent percents of frequency, where respondents indicated which of the three (3) program scenarios they perceived to be of benefit to the organization en total.)									
Control #1	1	1	1	1						= 1
Control #2					1	1	1			= 1
Control #3								1	1	= 1

Notice how the criterion of 'personnel' has been modeled in terms of costs (e.g. salaries and fringe benefits) and full-time-equivalent or personnel-unit requirements. In constrast, compliance of each alternative to existing policy is modeled via the use of ordinal measures based upon a previous evaluation of each scenario. The criterion of 'opinion' is synthetic, typically based upon a respondent's perception, and also modeled via ordinal scales. 'Preference' uses a composite measure based upon a previous survey of significant individuals. Finally, the control submatrix assures that (1) each option within a particular program will be evaluated and (2) one and only one funding alternative will be selected for each such program.

While many other illustrations and/or examples are possible, the widely varying budget reduction needs between institutions of higher education almost preclude the design of a 'conventional model' which would readily fit every university's needs. The flexibility with which the model can be designed to fit very individualistic needs is both benefit and pitfall. While flexibility allows a model to conform strictly to needs peculiar to any individual modeling situation, this same flexibility forces the developer to re-think the model's formulation for each new budgeting situation, especially as characteristics of supply and demand change to fit the fluid needs of a highly variant society.

SUMMARY AND RECOMMENDATIONS

Recent experience demonstrates that higher education, given its more exclusive authority over its own destiny, has been unable to deal adequately and decisively with fiscal emergencies. Declining enrollments, the resulting loss of revenues, and the increasingly marginal character of its faculty have mitigated against the university's attempts to better itself, its destiny and its mission in an ever changing society.

Reactions to fiscal exigency have ranged from the termination of all non-tenured faculty, to the accepted reduction in the salaries of tenured professors to stem the need to evaluate, compare and target instructional and service programs for reduced or discontinued funding.

Higher educational administrators have been unable to adequately analyzed the mass of available data which could shed some light on which programs could be reduced, and by how much. At the same time, these administrators need to know which programs require additional monies in order to continue their appointed, effective mission. It is the contention of this paper that the multiple alternatives modeling™ formulation for identifying graduated budgeting reductions for each university program provides the basis for a more appropriate and adequate response on the part of higher educational administrators to fiscal exigency.

The graduated budgeting scheme of MAM™ provides a scientific, data based and bias-controlled approach to targeting program budgets for reduction. While the model is complex to the novice, it is easily learned, employed and executed, given the availability of the appropriate computer software. Effectively, hundreds of higher educational programs (instructional, service and/or administrative) can be compared and contrasted through the use of hundreds of criterion references in order to identify appropriate levels of budgeting reductions (or increases) for each of the programs evaluated.

Research on the graduated budgeting model during 1981-83 demonstrated that the model effectively and efficiently targeted the appropriate programs and their respective level of reduced funding, based upon the criterion references supplied to guide the decisionmaking process. Post-hoc statistical analyses which matched the data used to the results generated significantly validated the model's technique and simulation processes.

Historically, the MAM™ approach has been applied to elementary school closures and budgeting reductions within public school districts. Other models which have been developed include: (1) matching instructional activities with market-available microcomputer hardware and software; (2) consolidation and merger of rural school districts; and (3) the reconfiguration of primary, elementary and secondary grade levels, by building, for medium-sized school districts.

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